YUMA MAIN STREET WATER TREATMENT PLANT
(Yuma Water and Light Company Plant,
Arizona-Edison Water Company Plant)
Jones Street at foot of Main Street
Yuma
Yuma County
Arizona

HAER No. AZ-33

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
National Park Service
Western Region
Department of the Interior
San Francisco, California 94107

HAER NO. AZ-33

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HISTORIC AMERICAN ENGINEERING RECORD

YUMA MAIN STREET WATER TREATMENT PLANT
(Yuma Water and Light Company Plant, Arizona-Edison Water Company Plant)

Location:	Between Gila Street and Madison Avenue (east-west) and the Colorado River and Jones Street (north-south), City of Yuma, Yuma County, Arizona U.S.G.S. 7.5 minute series Yuma East Quadrangle, Arizona-California Universal Transverse Mercator coordinates: Zone 11, Easting 723360, Northing 3623360
Construction Dates:	Initial construction - 1892 Additions and modifications - circa 1902-1994 HAER document components - circa 1902-1930
Engineer:	Circa 1902-1906 components - Hiram W. Blaisdell
Builder:	Circa 1902-1906 components - Hiram W. Blaisdell
Present Owner:	City of Yuma, Arizona
Present Use:	Municipal water treatment plant. The HAER components were abandoned circa 1954 and demolished in 1993 to accommodate new facilities.
Significance:	The HAER components of the Yuma Main Street Water Treatment Plant represent a largely intact example of an early water treatment plant utilizing settling reservoirs and slow sand filters. The historic value of the plant is furthered by the presence of the prototype Blaisdell Slow Sand Filter Washing Machine, which is the last-known example of the machine in existence.
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Date:	January 1994

INTRODUCTION

The Yuma Main Street Water Treatment Plant is a city of Yuma-owned facility and is located in the "Old North End" of the city. The site of the historic components of the plant is bounded by the Colorado River and the Southern Pacific Railroad tracks on the north, Gila Street on the east, Jones Street on the south, and Main Street on the west. Nonhistoric elements of the plant are located within and adjacent to the described area. The property is more precisely defined in figures 1, 16, and 17.

The historic components of the plant are situated entirely within the Yuma Crossing National Historic Landmark. Nonhistoric features of the plant are found within the landmark and immediately south of Jones Street, which is the south boundary of the landmark. Although the historic components of the plant are all within the landmark, their significance, with one notable exception, was not recognized when the landmark was established. Consequently, they are not listed on the National Register of Historic Places. The exception, the Blaisdell Slow Sand Filter Washing Machine, is, however, individually listed on the register for its significance to "industry" and "invention" in the early years of the twentieth century (see National Register of Historic Places nomination form, Blaisdell Slow Sand Filter Washing Machine, 1978).

This Historic American Engineering Record documentation of the Yuma Main Street Water Treatment Plant, including the Blaisdell Slow Sand Filter Washing Machine, was prepared to satisfy the provisions of a memorandum of agreement among the Advisory Council on Historic Preservation, the Bureau of Reclamation, and the Arizona State Historic Preservation Officer, with the city of Yuma, Arizona State Parks, and the Yuma Crossing Foundation in concurrence, after the historic elements of the treatment plant were determined to be eligible for listing on the register. As provided in the agreement, these historical and descriptive data were developed to mitigate the demolition of most of the historic components of the plant and the relocation of the Blaisdell Slow Sand Filter Washing Machine to a nearby site within the Yuma Crossing National Historic Landmark. The components scheduled for demolition had not been used since circa 1954 because of advances in water purification technology. Therefore, they were demolished in 1993 to accommodate new treatment facilities designed to meet the need of the rapidly increasing population of the Yuma area. This document was prepared before the demolition of the historic components and the relocation of the Blaisdell machine were undertaken.

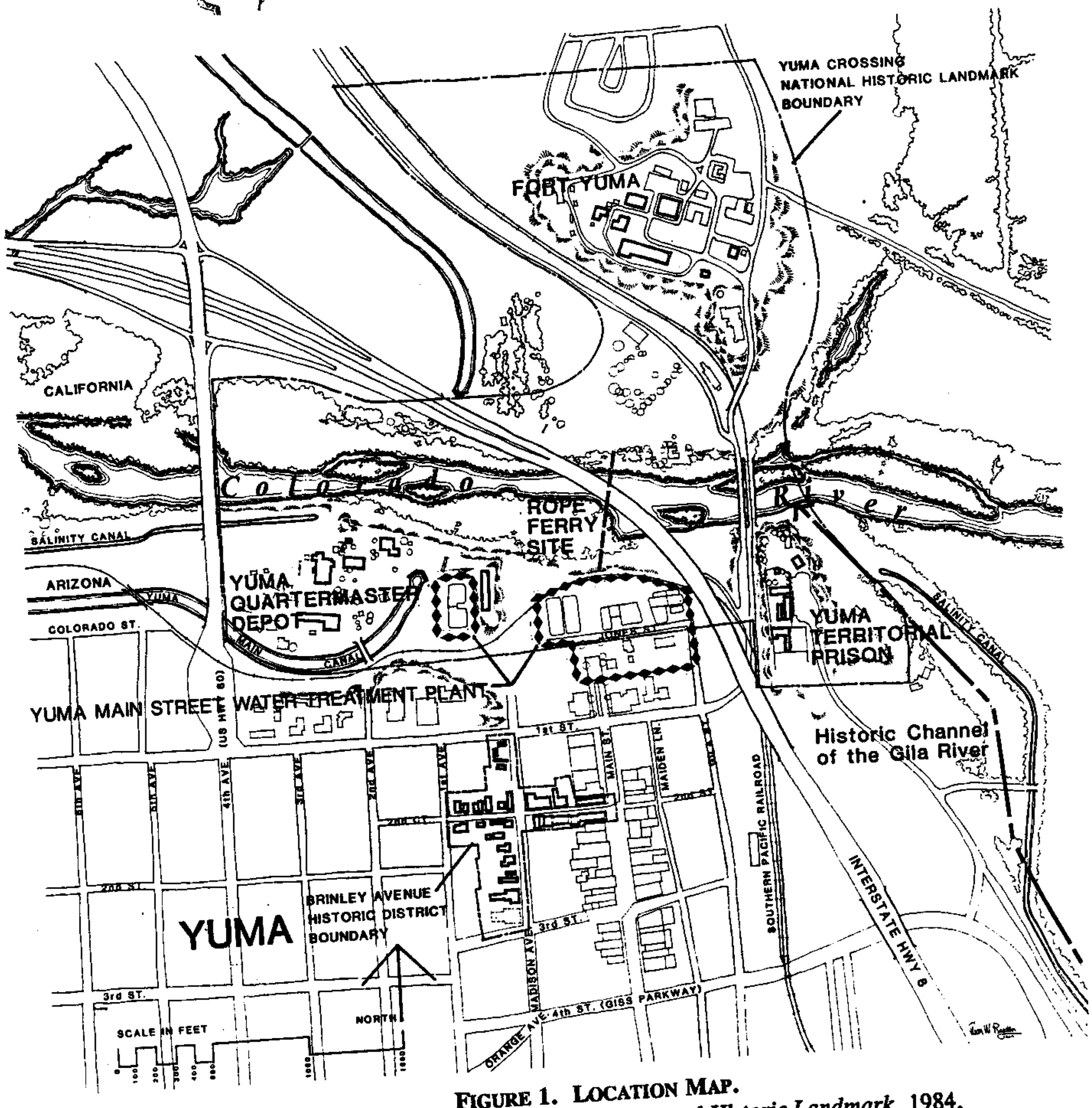

FIGURE 1. LOCATION MAP.
(From *Master Plan for Yuma Crossing National Historic Landmark*, 1984,
Gerald A. Doyle & Associates, Phoenix, Arizona.)

HISTORICAL CONTEXT

EARLY WATER TREATMENT TECHNOLOGY

Although slow sand filtration of domestic water supplies was well established in England and Scotland, and to a lesser extent in continental Europe, before the American Civil War, no such plants are known to have been in operation on this side of the Atlantic at that time. An early but unsuccessful attempt at filtration was made in Richmond, Virginia, in 1832, when an upward-flow, backwash filter was constructed three years after the first downward-flow, manually-cleaned filter was built in London, England. Not until 1855 was another municipal filtration facility attempted in the United States. It was a small charcoal, sand, and gravel strainer at Elizabeth, New Jersey. Little is known about the installation. Until the end of 1860 there had been constructed only 136 waterworks in the United States. All these are thought to have used water from springs or other sources free from turbidity and at least relatively free from pollution, which required no treatment.[1]

With renewed interest in water purification following the Civil War, development of waterworks in America progressed. In 1865-66 the city of St. Louis, Missouri, consulted James P. Kirkwood, waterworks engineer of Brooklyn, New York, to recommend improvements to its water supply. Kirkwood advised filtration be used. He then went abroad to gather information for the first book in any language to be devoted to the filtration of municipal water supplies. Water clarification and/or purification through settling and/or filtration had been employed in different places and at different times for many years; however, these processes were not clearly understood. Consequently, they were employed with haphazard specifications and varying degrees of success. Kirkwood's report, submitted upon his return to the United States in 1869, described and illustrated the filters and filter galleries used in nineteen European cities, including Berlin, Altona, Nantes, Angers, Lyons, Toulouse, Marseilles, London, Leicester, York, Liverpool, Edinburgh, Dublin, Perth, and Genoa.[2] Trying to gather the knowledge of the world for use in America, Kirkwood also included in his report the historical precedent for the filtration of water.

Sanskrit medical lore and Egyptian inscriptions afford the earliest recorded knowledge of water treatment. The *Sus'ruta Samhita*, a body of medical lore said to date from 2000 B.C.E., declares: "Impure water should be purified by being boiled over a fire, . . . or it may be purified by filtration through sand and coarse gravel." The earliest known depiction of an apparatus for obtaining clarified liquid was found on the walls of an Egyptian tomb from the reign of Amenophis II in the fifteenth century B.C.E. (figure 2).[3]

Vitruvius, in 15 B.C.E., recommended that cisterns be constructed in compartments and that water be transferred from one to another to allow mud to settle out. Pliny (c. A.D. 77) said that polenta (meal porridge) added to bitter water would render it potable in two hours and that a similar effect could be achieved using chalk from Rhodes or argilla (white clay) from Italy.[4] This is the first mention found of lime and aluminous earth used as coagulants.

FIGURE 2. ANCIENT EGYPTIANS SIPHONING EITHER SETTLED WATER OR WINE.[5]

In Sir Francis Bacon's *Sylva Sylvarum, or a Natural History in Ten Centuries*, published in 1627, a year after his death, ten of the thousand "experiments" recorded dealt with water purification. Filtration, boiling, distillation, and clarification by coagulation were reviewed.[6]

The first illustrated description of sand filters was published in 1685 by Luc Antonio Porzio, an Italian physician who had gone to Vienna in 1684. The Austro-Turkish War in 1685 led him to write a book concerning the health of soldiers, probably one of the earliest treatises published on mass sanitation. In his treatise Porzio described his observations made in Venice in 1683 on water purification. In Venice the primary water supply was filtered rain water. Because Venice is a series of islands, there was not room to build large storage and settling reservoirs, so hundreds of cisterns were built. Rain water, or water brought from nearby rivers in boats, was conveyed by pipes or canals to the cisterns. Many, if not all, of these were surrounded by sand filters (figure 3). It is not known how early and how frequently these filters were provided. However, it was probably sufficiently early to place Venice first among the cities to be largely supplied with filtered water. The water came into the wells "perfectly purify'd" because all around the wells was "a large quantity of Sand, which the Venetians call the Spunge of the Wells." Surrounding the sand was "a kind of Fence" of "fat earth . . . which hinders the salt Water from penetrating into the Well." Water flowed through the sand and the sides of the well, falling into it "clear and pure," losing the "Taste and Smell of Pitch and Tar" it acquired from contact with the "small and pitch'd Boats" used as carriers.[7]

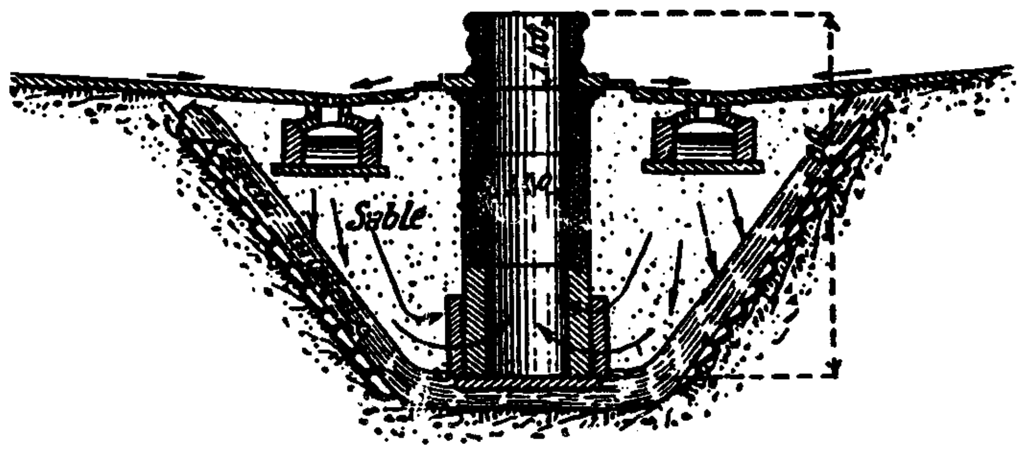

FIGURE 3. CROSS SECTION OF VENETIAN FILTER CISTERN.[8]

In *Domestic Medicine* (1769), by Dr. William Buchan of Edinburgh, Scotland, is found the first positive statement that water should be purified, if need be, before it is supplied to great towns. Although he did not list them, Buchan said that there were generally known methods of rendering water clear by filtration and that many diseases might be caused or aggravated by bad water.[9]

The first filter to supply water to an entire town was completed at Paisley, Scotland, in 1804. The water it supplied was carted to consumers.[10] In 1807 Glasgow, Scotland, was the third city to have a filtered water supply. Unlike its predecessors, Paisley and Paris, where filtered water was carted to customers, Glasgow was supplied by pipes.[11]

In 1827 slow sand filters designed by Robert Thom were put into use at Greenock, Scotland, and similar filters designed by James Simpson were completed at London in 1829. Thom's were cleaned by reverse-flow wash; Simpson's by surface scraping.[12] Thom's filter design was followed in only a few places, most of them in Scotland. The Simpson design became the model for English slow sand filters. It was so effective in removing sediment and improving the appearance of water that in 1852 its use was required by law for all London water companies. The example of London was soon followed by other cities, both in England and on the Continent. With Kirkwood's book it became the model for water filters throughout the world.

The British contributed little to filter design after the days of Simpson, but much to the knowledge of the reduction of bacteria by slow sand filtration. In England new ideas of what filtration could do began to develop before the middle of the nineteenth century. By the 1860s it was generally acknowledged by scientists that the incidence of cholera decreased after the introduction of slow sand filtration.[13] The *Encyclopedia Britannica*, which in earlier editions had not reflected progress in water purification, put itself abreast of scientific progress in 1875. It stated in its article on filters that putrescent organic matter may include "minute invisible disease germs" which should be removed from drinking water. Many outbreaks of "virulent disease, such as typhoid," had been "clearly traced to water so contaminated."

In 1882 Dr. Robert Koch, of Berlin, Germany, discovered the microscope gelatin-plate process, which made it possible to fix, cultivate, and even count the microorganisms in any sample of water. As the use of this process, along with the knowledge of Louis Pasteur's discoveries concerning bacteriology, spread, so did the biological analysis of water used to investigate the purification phenomena of sand filtration.[14]

Before a meeting of the Institute of Civil Engineers in London in 1886, Percy F. Frankland announced, to the astonishment of most of his listeners, that filtration removed most of the bacteria from water. This had recently been proved by counts of the bacteria in water samples supplied by London water companies. Frankland's pronouncement is noteworthy.

> Thus for the first time a definite conception has been obtained of the effect of sand filtration upon these lower forms of life. Hitherto those who were acquainted with the size of these minute microscopic organisms on the one hand, and with the dimensions of the pores in a sand filter on the other, have believed that little or no barrier could be offered to these organisms by the comparatively spacious pores of the filter, and even the strongest advocate of sand filtration could not have reasonably anticipated that filtration through a few feet of material could effect this remarkable reduction in the number of micro-organisms. . . .[15]

St. Louis decided before Kirkwood's return not to institute filtration. However, late in 1872, as a product of his research, Kirkwood designed the first successful slow sand filters in the United States for Poughkeepsie, N.Y., a city of approximately 20,000.[16]

New means for disseminating information on water purification came into being in the United States during the 1880s and 1890s. The American Water Works Association was established in 1881, and the New England Water Works Association in 1882. Each published its proceedings. National engineering, chemical, and bacteriological societies were also established and published journals. From 1890 to 1900 these journals spread knowledge of the new methods for purifying water and the practical application of these methods.

At the Lawrence Experiment Station of the Massachusetts State Board of Health, established in 1887, more than 12,000 bacteriological tests were conducted to investigate the efficiency of 20 filters of different construction and operation. The tests indicated that 98.54% of the bacteria in the Merrimac River water were removed by filtration. Based on these results, a water filtration plant for the city of Lawrence was designed and built under the direction of civil engineer Hiram Mills. It went into use in September 1893.[17]

In 1893-94 what came to be known as the Mills-Reincke phenomenon was first observed. It was noted independently by Mills and Dr. J. J. Reincke, of Hamburg, Germany, that purification of polluted public water supplies was causing a reduction in the general death rate of each of these cities far beyond its predicted effect on typhoid and cholera.[18]

Dr. Reincke, two years after Hamburg was swept by cholera and began filtering public water, noted that the low mortality rates were most apparent among infants born after the epidemic. He attributed the change to the improved water supply and "the influence of the water on the mortality of children from diarrhea and gastrointestinal diseases."[19]

In Lawrence the deaths from typhoid fever dropped from an average of 52 per year in the six years before the introduction of filtered water to an average of 12 per year when using filtered water. In addition, deaths from all diseases decreased after the filter was built. Using filtered water there was an average of 300 fewer deaths per year than there would have been if the death rate had continued as before. Mills said that there had been "danger both constant and grave" in the use of the unpurified water for drinking purposes.[20]

> . . . as far as cholera and, particularly, typhoid, were concerned, the influence of Pasteur that began to be felt after 1890 sparked off a real debate on the pollution of water by microbes. . . . the classic distinction between stagnant water and running water still persisted, with the latter being considered healthier. Under Pasteur's influence, this criterion lost some of its importance; the notion of bacteriologically pure water became fundamental, at the same time as a new obsession with pure water . . . was spreading in certain quarters, with people constantly washing their hands and refusing to drink water unless it had been filtered or boiled.[21]

Knowledge of the microbial source of typhoid fever and the way in which it spread forced the political and scientific authorities into sudden awareness of the problems of public health. The reduction of typhoid in Lawrence and the prestige of the Massachusetts Board of Health established American confidence in filtration at a time when epidemic water-borne typhoid was taking a heavy toll, and when American cities and water companies were at last willing to pay the cost of efficient purification. An entire sanitary system based on the newly discovered hygiene standards was rapidly put in place.[22]

In 1868, when Kirkwood submitted his report to the city of St. Louis, the only recognized method of filtering water was to pass it through sand at a rate not more than three million gallons per acre daily. The only resource of note was Kirkwood's report, which, written before the days of bacteriology, related almost entirely to the clarification of water. Hardly anything was known about the actual operation of the plants in use or about what might be accomplished by more carefully designed works. At that time sand filters in the United States had an aggregate area of only 1.5 acres, with a capacity of four million gallons per day. By the turn of the century all of this had changed.

In its November 10, 1900, issue, *The Engineering Record* reported:

> As one city after another gives up the use of raw surface water and supplies clear and wholesome water in its place, the remaining cities feel more keenly the disgrace of impure and muddy water, and stronger and stronger pressure is brought to bear upon municipal authorities to provide suitable filtration plants. It may thus be confidently expected that the next few years will see the construction of a large number of filtration plants, and that more thorough work will be insisted upon, and that this will continue until the use of raw water is as uncommon and looked upon with as little favor as it is in Europe.[23]

By the close of 1900 purification plants in use in the United States had increased to about 19 acres with a daily capacity of 57 million gallons, and accurate information as to what these plants accomplished became available. There were approximately 22 slow sand filters at various locations in the United States including Poughkeepsie, N.Y.(1872); Lawrence, Mass.(1893); Mt. Vernon, N.Y.(1894); Rock Island, Ill.(1899); and Albany, N.Y.(1899).[24]

The desire to purify water rapidly, and with small filtering areas, led to the construction of new filters in the 1880s and 1890s that operated at rates many times as great as slow sand filters. In connection with these rapid filters, an agent, usually alum, was applied to the raw water to coagulate the impurities and allow them to be removed more quickly. Most of the early American rapid filters operated under considerable pressure. Often this was provided by pumping from the water source through a closed filter tank and then into the distributing lines. Once water had been treated with coagulant to settle it, it could be pushed much faster through the filter material, but only if the filter could be kept constantly clean by mechanical means. Closed tanks had to be small containers so that cleaning mechanisms were not too cumbersome. Filters operating at high rates, utilizing mechanical cleaners, and generally depending upon the use of a coagulant were called "mechanical filters" or "American filters."[25] Mechanical filters using a coagulant were best suited for the treatment of muddy water, which quickly clogged sand filters. Sand filters were found better, and often more economical, than mechanical filters to treat clear but sewage-polluted waters without coagulant. Various claims as to the relative merits of the two systems of filtration were made, and discussion of the merits of the two types delayed, in many cases, the installation of filters of either type. Mechanical filters were covered by patents, and companies operating under them entered into contracts to purify municipal supplies, guaranteeing results. This arrangement often appeared more attractive to small communities than the construction of filters upon independent plans, despite the relative merits of the methods. As a result, numerous contracts were made for mechanical filters, and it seemed at one time that this method might be used almost exclusively in this country.[26]

However, toward the end of the century it was proved that slow sand filters, perfected long before bacteria were known to exist, were as efficient in removing bacteria as in effecting their original objective—clarification.[27] They were found preferable to mechanical filters for their action in removing bacteria, and because they did not require the addition of chemicals, which were not acceptable to water users of the time. Chlorine treatment in association with mechanical filters came into use circa 1915 but was used generally for water supplied to mills and factories. By the 1930s chlorine treatment, used to kill bacteria both before and after filtering, became accepted for domestic use, and rapid mechanical treatment quickly replaced slow sand filtration. Until that time slow sand filters provided the only system assuring bacteriological purity as well as clarification without the addition of chemicals.[28]

Slow sand filters carried with them from their inception the problem of how to clean them without having an entire set of duplicate filters to use during the lapse. An 1825 article is the first critical review of filters for city water supply that has been found. It points out that the main cause of failure in filters was the lack of means for cleaning them in place.[29] The cost of cleaning them, by dropping the water levels and manually scraping off the sand constituted almost the entire operating expense.[30] Intermittent filters, taking the Lawrence filter as their model, were washed by reversing the flow of the water to blow off the top layer of sand. This, like scraping, required another set of filters to use while cleaning and ripening the sand.[31] Mechanical cleaning of sand filters, beginning with the invention of the Blaisdell Slow Sand Filter Washing Machine in Yuma, Arizona, encouraged the installation of slow sand filters throughout the United States for some time following the turn of the century.

EARLY DEVELOPMENT OF WATERWORKS IN YUMA

In 1863, when Kirkwood's report brought water quality to the forefront of American scientific interest, water purification technology began to develop in New York and Massachusetts. However, towns such as Yuma, where the arid climate intrinsically linked the development of the town to the acquisition of water, had yet to secure a method of steady municipal supply. The Colorado River has always been considered the only suitable source of water for Yuma. During the Gold Rush of 1849, a community developed at the "Yuma Crossing," one of the few points where travelers could cross the Colorado River. Through the years, it became known as Colorado City, Arizona City, and eventually Yuma. Most residents were associated with the military, the mines, the Colorado Steam Navigation Company, and, later, the Southern Pacific Railroad, or with the selling of merchandise to supply these entities. Many wells were dug in the vicinity, but always the high salt content of the water rendered them useless. Consequently, the area has always relied on the water supply drawn from the river.[32] In the river water a heavy sediment, amounting to about one-fifth of the volume, created a serious problem. To overcome it, water had to be "settled" before it could be used.

The first waterworks at the Yuma Crossing appears in an 1853 painting of Fort Yuma, directly across the river from the site of the Yuma Main Street Water Treatment Plant. The painting shows either a burro-driven or a mule-driven pump with a pipe running to a stone reservoir on a hill.[33] A photo from about 1864–66 shows another stone reservoir at the Yuma Quartermaster Depot, a few hundred feet west of the site of the Yuma Main Street Water Treatment Plant. This reservoir has been restored but is not in use (figure 4).

An army inspection report of November 7, 1866, described the antiquated water systems of the fort and depot and recommended the installation of steam engines to power the pumps.

> The present process of supplying the Post with water is old-fashioned, expensive, and insufficient. It is done by an 8 horse power machinery. The expense may not have been felt very heavily, still the method is a slow and shiftless one. The forage alone, which is fed to the 6 or 8 mules, not to mention other items, would go far in a year's time towards substituting a 10 horse steam engine. I therefore recommend that one be furnished to the Post, and another to the Depot in supplying water to extinguish fire and for other purposes. . . .[34]

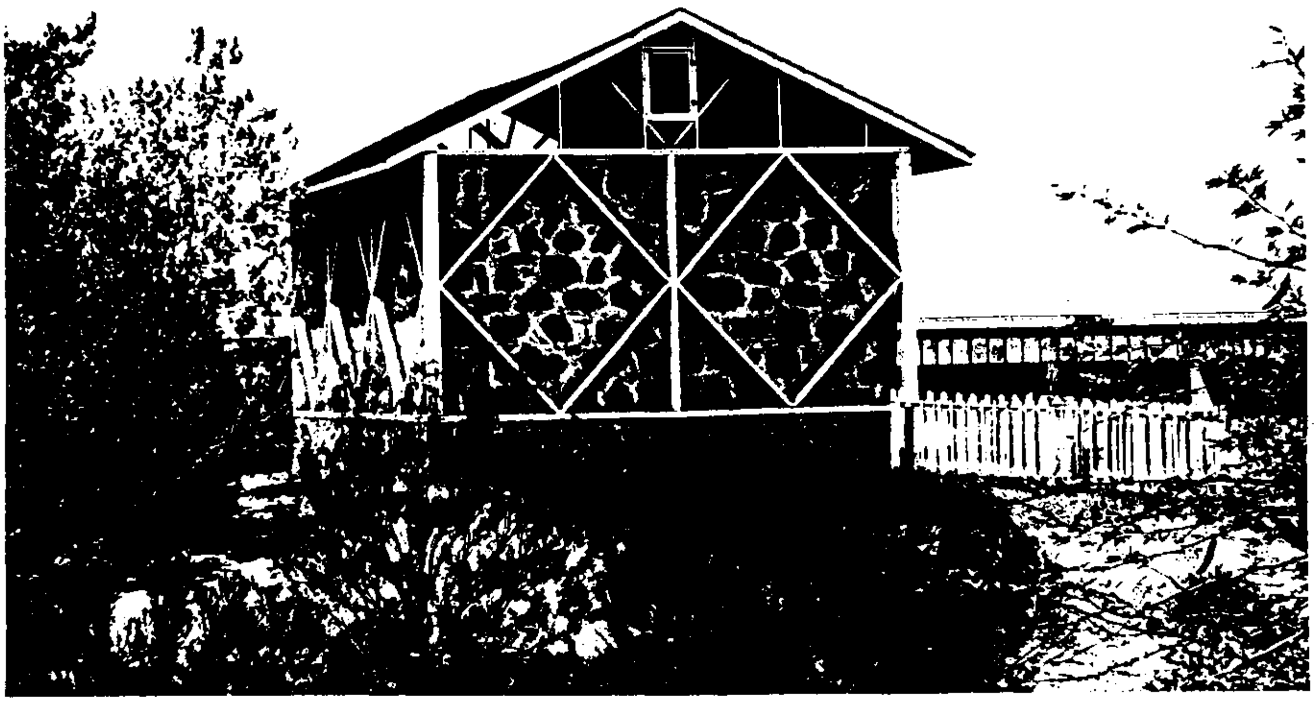

FIGURE 4. RESTORED WATER RESERVOIR AT THE YUMA QUARTERMASTER DEPOT.

A map of the Quartermaster Depot, dated March 1870, does not show such equipment, although it may have been present. However, a map drawn in 1871 shows a pump at the river's edge and a system of distribution pipes from the reservoir to the various buildings of the depot. Apparently the water was clarified by settling in the reservoir.

The next waterworks at Yuma was constructed by the Southern Pacific Railroad in 1877 at the foot of Madison Avenue, a few hundred feet west of the site of the Yuma Main Street Water Treatment Plant (figure 5 and Field Records photographs 1 and 2). Water was pumped from the Colorado into settling reservoirs located on a hill immediately west of the Southern Pacific's river bridge. After water was settled, it flowed by gravity through a wooden line to the Southern Pacific yard and roundhouse on Madison Avenue between 4th and 5th streets and to the Southern Pacific Hotel at the south end of the bridge. The railroad also sold water to the school on Main Street and to a limited number of residents living along the route of the water line.[35]

FIGURE 5. SOUTHERN PACIFIC RAILWAY RESERVOIRS

In 1889 a waterworks was constructed at the Yuma Territorial Prison, a few hundred feet east of the site of the Yuma Main Street Water Treatment Plant and immediately west of the former confluence of the Colorado and Gila rivers. The pump and settling basin had capacity sufficient to serve only the prison. The circular stone reservoir, with a roofed gun platform on top, still remains at the Yuma Territorial Prison State Historic Park on Prison Hill (figure 6).

Thus, with the exception of a few residents along the route of the Southern Pacific's water line, there was no water system with the capacity to serve the townspeople. William Westover, in *Yuma Footprints* (1966) described Yuma, at the turn of the century, as

> . . . a squalid community of some 1,500 people. . . . The main business section extended from the Colorado River to Second Street, and south of Second street was the grammar school, the Catholic Church, and the residences of many of the prominent citizens of that day.

FIGURE 6. STONE RESERVOIR AT THE YUMA TERRITORIAL PRISON.

> The domestic water supply consisted of raw untreated Colorado River water half mud and half liquid. Each evening my mother would fill a large wooden barrel at the back door with this water and allow it to settle overnight, and that which was on top the next morning was our drinking and cooking water for the day.[36]

Many of the first residents of Yuma paid Quechan (Yuma) Indians 25 cents per barrel to fill old whiskey barrels that they kept at their homes. The Indians hauled water from the river in five-gallon cans tied to the ends of poles about six feet long that were carried on their shoulders. Water was kept in two or three barrels in each home for settling. Once settled, it was stored in *ollas*, which cooled the water by evaporation from their porous walls.[37]

In 1880 two Mexicans, Chono Lorona and Ramon Zapata, started a small but thriving water business. They had a barrel with a faucet mounted on a cart which they used to deliver water to settling barrels throughout the town (HAER photograph AZ-33-1). Their business ended in 1892, when Hiram W. Blaisdell formed the Yuma Water and Light Company and began supplying water and electricity to the community.[38]

HIRAM W. BLAISDELL, YUMA PIONEER ENTREPRENEUR

BLAISDELL'S LIFE

Hiram Wheeler Blaisdell was born September 8, 1851, at Waltham, Massachusetts (HAER photograph AZ-33-2). He attended Massachusetts Institute of Technology at Cambridge as a "special student" from 1869 to 1873 but did not graduate. A special student at M.I.T. then could have attended night classes or summer classes only, or could have been a regular student who concentrated entirely on special subjects, such as mining or civil engineering, but who did not take enough of other required subjects to receive a degree.[39]

As a young man Blaisdell gravitated to California, where he was involved in land development.[40] We first hear of him in Arizona on February 26, 1884, when he was appointed postmaster at the Esperanza mining camp about 18 miles south of Tucson. Late in 1884 he and his brother Frank G. Blaisdell arrived in Yuma, then a town of about 1,000 people.[41]

While Hiram was working as a civil engineer for mines in the area, he became convinced that the desert land, given water, would raise bountiful crops. Consequently, between 1886 and 1889, he was involved with the building of two canals, the Araby and the Mohawk.[42] On February 25, 1888, the *Arizona Sentinel* made reference to the Araby Canal, which proposed to take water out of the Gila River at the eastern end of the Araby Valley and irrigate 12,000 acres. Among the owners of this canal was Hiram W. Blaisdell, who was involved in its financing, engineering, and building. In 1889 he also participated in the building of the Mohawk Canal.[43]

On November 16, 1891, the Blaisdell brothers bought 148.7 acres in the rich bottom land along the Gila, which became known as the "Blaisdell Ranches."[44] With irrigation from the river, the ranches successfully produced vegetables and fruit.[45] The citrus grove on the ranch was one of the first in Arizona and probably the first in the Yuma area. Hiram's lifelong affair with citrus had begun in California, where he was acquainted with Luther Burbank. Blaisdell obtained his first trees from the noted horticulturist's nursery in Santa Rosa.[46] (Luther Burbank was born in Lancaster, Massachusetts, in 1849 and moved to California in 1875.)

On February 22 and 24, 1891, two floods washed away miles of railroad track along the Gila and most of the Blaisdell Ranches. Fortunately, Hiram was involved in other activities. Newspaper clippings from the *Arizona Sentinel* report that he was also in the mining business. In 1891 he apparently served as manager of the Cargo Muchaco Mine and superintendent of the Paymaster Mine. At about this same time he also started the Yuma Printing and Publishing Company, which produced the *Yuma Times* newspaper (see Field Records).

On January 7, 1893, the Southern Pacific Railroad acquired higher ground farther south of the river for a new railroad station.[47] The site was 2½ miles southeast of the Blaisdell Ranches, so the railroad named the station "Blaisdell." A small community grew up around it. A railroad timetable of March 1897 shows Blaisdell to be 13 miles east of Yuma (figure 7).[48]

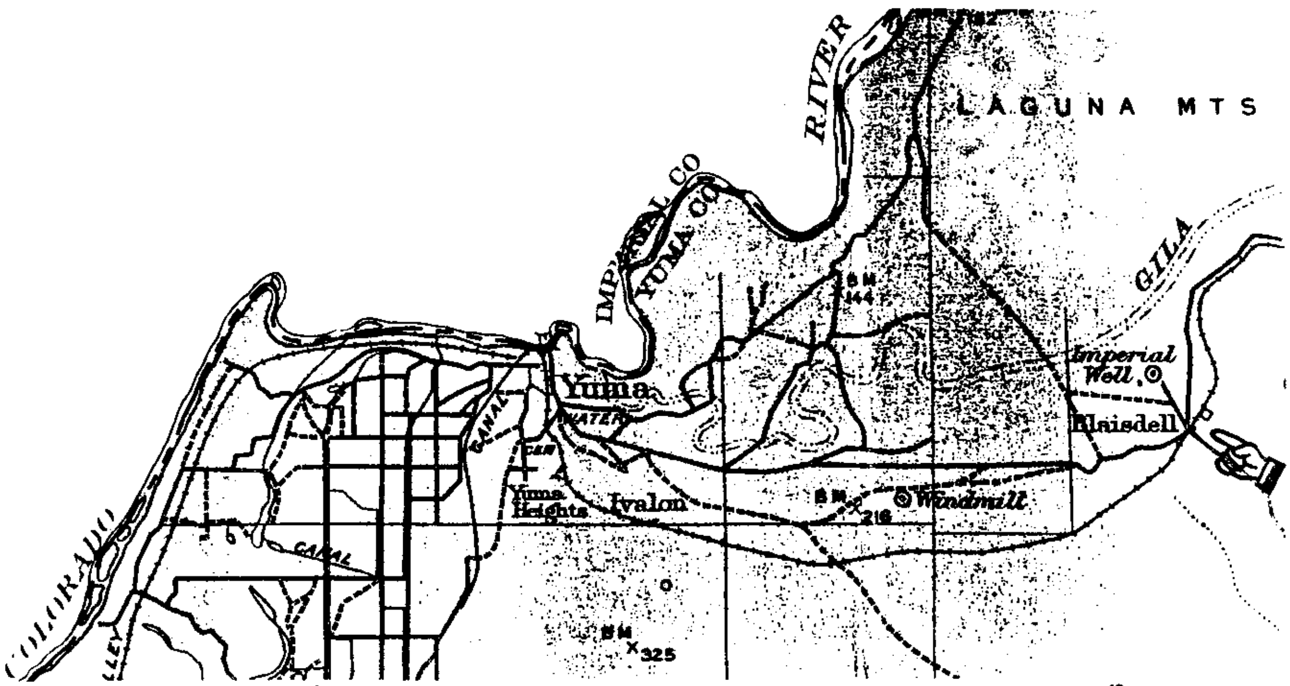

FIGURE 7. RAILROAD TIMETABLE MAP SHOWING BLAISDELL AND YUMA.[49]

Hiram married Mrs. Alice B. (Prescott) Linder, of Concord, Massachusetts, October 11, 1893, at Concord. She was the daughter of Col. George L. and Sarah Barker (Eads) Prescott and was born November 12, 1853. Hiram and Alice had no children. Their only known residence in Yuma was a large adobe house which they built on Orange Avenue. It later became known as the Clymer Building but is no longer in existence.[50]

CITRUS IN YUMA

It was once thought that much of the land around Yuma was worthless because of the low rainfall and the difficulty of supplying it with water. However, Hiram Blaisdell, as an engineer, irrigator, and pioneer citrus grower, recognized early that the rich soil and persistent high temperatures in conjunction with adequate irrigation water could make the Yuma Mesa, an elevated area a few miles south of the town, "a great forcing house, a conservatory for the growing of fruits, vegetables, etc., that struggle to attain maturity elsewhere."[51]

In 1892, the Yuma Water and Light Company's first year of operation, Blaisdell planted an experimental orchard of 110 acres on the Yuma Mesa. It included oranges, lemons, limes, peaches, apricots, plums, prunes, and figs. The orchard was subsequently enlarged, and the area became known as "Blaisdell Heights" (HAER photograph AZ-33-3). A University of Arizona Experiment Station bulletin referred to Blaisdell's Yuma Water and Light Company as a pioneer in the use of high duty pumping machinery for irrigation purposes.

> This company concluded to put in a pump to force water from the river to the Mesa where it owns 3,000 acres of land. Aside from pumping, the only way of getting water to this land would have been to build a high dam across the river or carry a canal a long distance up the river, either of which was deemed too expensive for the results to be obtained. But the Mesa was thought to be so well fitted for raising tender and early fruits and vegetables that the expense of raising water even to a height of 80 ft. would be warranted.[52]

With his produce, Blaisdell convinced the residents of the area that they had excellent citrus lands which could be reclaimed by irrigation, and that the lands would support very profitable agricultural enterprise which would more than justify the expenditure for the extensive pumping.[53]

> The incentive to grow oranges in the arid Southwest, where climactic conditions are trying to the growth of trees, is the high price received for the fruit. Fruit from this region is in considerable demand in the Northern markets, chiefly on account of its remarkable earliness. The oranges are also sweeter and are much deeper colored than those grown in humid and less sunny regions.[54]

Based on reports of excellent produce from the Yuma area, Laguna Dam was constructed in 1905–06. It was one of the first projects of the Reclamation Service (now the Bureau of Reclamation). The dam was built to irrigate lands along the Colorado River above and below Yuma for the purpose of large-scale agriculture.[55] By 1906 such progress had been made in irrigated agriculture that the *Arizona Sentinel* on March 7, 1906, could say, "Adios Yuma, the 'hottest place in the world.' Hail Yuma, the Mecca of the fruit grower!" Mose Drachman, a Tucson councilman, brought a branch bearing five lemons, which together weighed four pounds, from Blaisdell's fruit grove on the Yuma Mesa to Tucson, where they were given to the chamber of commerce for exhibition.

Large-scale commercial citrus farms were established in Yuma about 1916. Yuma County's citrus industry continued to expand through about 1960, as the encroachment of urbanization on established citrus areas, especially in Southern California, reduced production there.[56] Today there are about 23,000 acres planted in citrus in the Yuma area. Most of this acreage is located on the Yuma Mesa. Due to the limitation on water allotted by the Bureau of Reclamation, the growth in citrus acreage has reached its peak.[57]

Although citrus was the principal produce of the Yuma Mesa, other crops were found to grow well in the surrounding valley. They included corn, potatoes, turnips, squash, sugar cane, sorghum, peanuts, alfalfa, barley, cucumbers, tomatoes, melons, onions, radishes, beets, cauliflower, cabbage, and lettuce.[58] Many of these, particularly winter vegetables, are still commonly grown in Yuma and its environs.

KING OF ARIZONA MINE

In 1899 Blaisdell bought into the King of Arizona Mine. He served on its board of directors for eight of its eleven years of continuous operation. The *Phoenix Daily Herald* on March 3, 1899, reported: "H. W. Blaisdell has taken hold of the King of Arizona mine and will make an effort to secure water at the mine. He believes the King is one of the greatest gold mines of the southwest and proposes to make it a leading producer." [59] Initially, ore from the mine was milled at the Mohawk Mine, as there was no water available to run a mill at the King of Arizona. The lack of water was also a problem for the men living in the mining camp, who hauled domestic water to their camp from distant sources in wagons.[60]

Blaisdell built a large frame for a drill about three miles from the mine and drilled down more than 600′ without hitting water. After a delay, during which larger equipment was acquired, a well was successfully finished. In 1898 water from this deep well and another shallower well about 17 miles away enabled the company to install and use a large cyanide mill, which had formerly operated at the Picacho Mine in California. Ore was dry crushed to save water and then run into 250-ton tanks, where a solution of cyanide and water was used to leach out the gold.[61]

The King of Arizona, from which the Kofa Mountains take their name, was one of the richest gold mines ever discovered in Arizona. Some ore assayed as high as $3,000 a ton. The mine operated continuously from August 1899 to July 1910, producing on an average 200 tons of ore per day. The King of Arizona Mining and Milling Company also owned the Homestake, the Last Hope, and the Mucho Bueno mines.[62]

BLAISDELL'S CALIFORNIA COMPANIES

Meanwhile, Blaisdell became involved in land development in Imperial County, California, and in manufacturing and marketing filtration and mining machinery in Los Angeles. In 1907 he left his brother, Frank, to manage the Yuma Water and Light Company and, selling his interests in the mining company, pursued other business interests until his retirement.[63]

Blaisdell claimed residency in Los Angeles on a patent dated June 28, 1904, and lived there full time by 1906, when the Blaisdell Filtration Company first appeared in the Los Angeles Business Directory. By 1907 the Blaisdell Company, making cyanide milling machinery, had branched off from the Blaisdell Filtration Company. Both companies were located in the same room of the Pacific Electric Building on Main Street. A third company, the Blaisdell Coscotitlan Syndicate, was listed at the same address. In the 1910 directory the Blaisdell Company had added "construction" to its activities. In 1911 only the Blaisdell Company was listed, and the company's address had changed to 608 S. Main Street. Its business was described as "machinery." In 1912 Hiram's brother relocated from Yuma and joined the company as secretary and treasurer (see Field Records).

In 1913 the Blaisdell Filtration Company ("filter cleaning machinery") is again listed separately from the Blaisdell Company ("mine, cleaning machinery"). In 1914 and 1915 only the Blaisdell Company ("mining machinery") is listed. From 1916 to 1922 both the Blaisdell Company ("machinery") and the Blaisdell Filtration Company ("filter cleaning machinery") appear in the directory.

After 1922 no listings appear for any of the Blaisdell companies. It was probably about this time that Hiram retired and moved to Philadelphia, Pennsylvania. There he and his wife died, she on March 13, 1930, and he on May 11, 1934.[64]

EARLY HISTORY OF YUMA MAIN STREET WATER TREATMENT PLANT

BEGINNINGS

Hiram Blaisdell saw the possibilities of a great future for Yuma if it were to develop a municipal water system and an electric plant, like those being installed throughout the country at the time. For Blaisdell the technology was readily available. Steam engines used to drive water pumps and electric generators were similar to those he had been using to power mechanical equipment in the mines. A mesquite-fired boiler provided steam to drive an engine that could be harnessed to a variety of machines. With the addition of a generator, a simple electric power generating plant was created and with the installation of a pump a rudimentary waterworks was realized.

The Yuma Territorial Prison had installed a small 12-HP generating plant in 1885; by 1892 it was in a state of disrepair. The prison generating plant was also seen as a security problem by the warden, as inmates who operated the generator could not be confined in their cells at night. So when Blaisdell proposed, on April 7, 1892, to supply the prison with both light and water, the warden was eager to accept the offer. Another important commitment for service came from the town, when on May 14, 1892, the town council granted Blaisdell a franchise to supply Yuma with electricity and water for the next 50 years.[65]

At the end of May Blaisdell returned to Boston and told several business associates of the great investment opportunities in Yuma and on the Colorado River, "The Nile of the West." He and four financiers formed the Yuma Water and Light Company in Saco, York County, Maine.[66] The articles of incorporation are dated July 15, 1892, and list the owners as C.P. Hemenway, John Dodd, T. Quincy Browne, William L. Parker, and Hiram W. Blaisdell. In August 1892 the construction of the Yuma Water and Light Company plant was begun on the site of the present facility, and in February of the following year it began operation (figures 8, 9, and 10, and HAER photograph AZ-33-4).[67]

The Thompson-Huston bipolar electric generator that Blaisdell brought to Yuma was powered by an Oman 25-HP steam engine. With a total capacity of 120 kilowatts, the generating plant supplied power to the waterworks, prison, and residents of the town.[68] The steam engine was described in the *Arizona Sentinel* on August 13, 1892, as "one of the finest ever brought into the Territory, of one-hundred and twenty horsepower, having a fly wheel that weighs seven tons." The plant had a control board fashioned in Yuma of redwood.[69]

Water for distribution through Blaisdell's new lines was first purchased from the Southern Pacific Railroad.[70] The water passed from the river to a settling basin on the hill immediately west of the railroad depot (figure 5). From there it was pumped up to the Yuma Mesa through 2½ miles of 26″ diameter redwood pipe, similar in construction to a barrel[71] (Field Records photographs 35, 36, and 37). A one-million-gallon reservoir was built on the Mesa, near what is now the intersection of 5th Avenue and 14th Place[72] to store water for use when the pumps were not working. The reservoir was a shallow basin, 150′ square, formed by earth embankments lined with a 3″ layer of concrete. The pumping plant consisted of two 150-HP boilers, a Brown 18″

x 42" 165-HP automatic cutoff condensing engine, moved from the Cargo Muchaco Mine, and an Allis double-acting plunger pump.[73] Because the water had to be raised 80' to the Mesa, it was impossible to use a standard centrifugal irrigating pump. Instead, a special system with superior durability and economy was designed and constructed. The condensing engine was connected to the plunger of the pump by extending the piston rod through the rear cylinder head of the engine. This method of connection allowed the power generated by the engine to be transmitted to the pump without the intervention of cranks.[74]

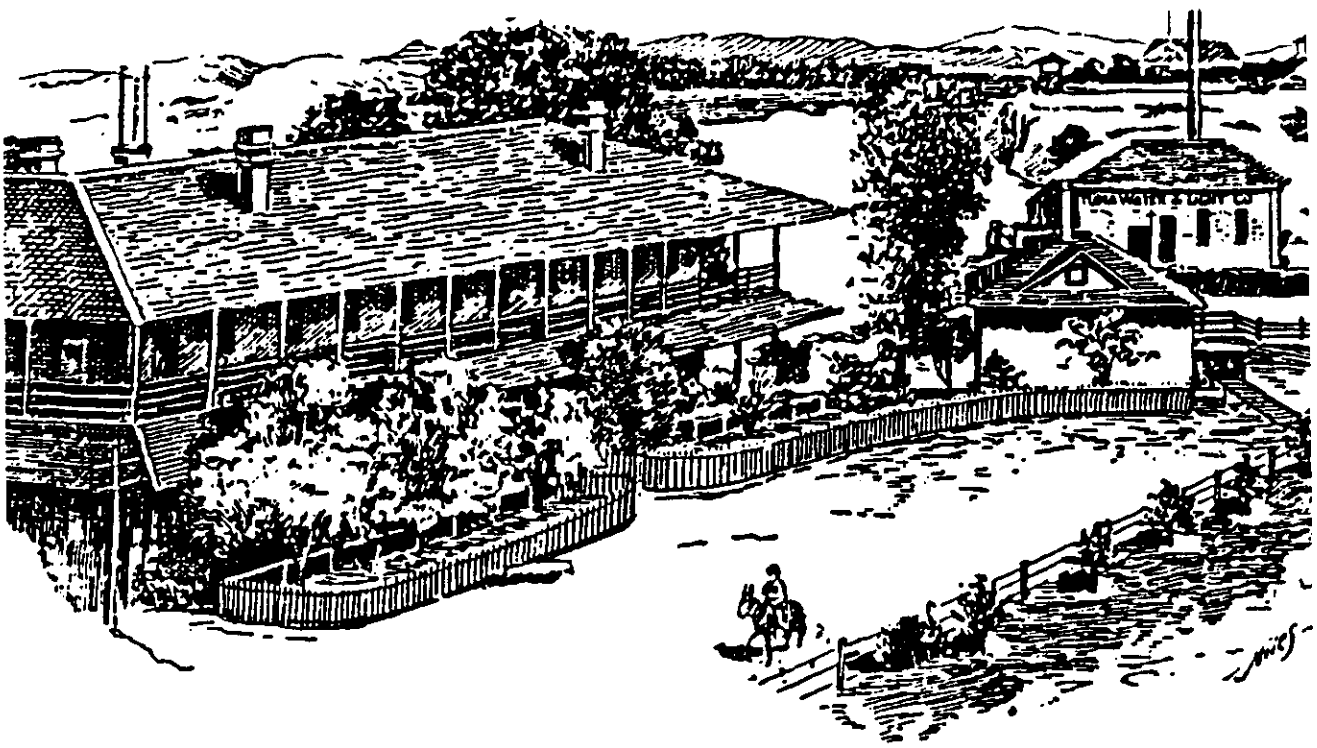

FIGURE 8. SOUTHERN PACIFIC HOTEL (LEFT) AND
YUMA WATER AND LIGHT COMPANY (WITH TALL STACK), 1893.[75]

The pump had a 17" plunger with a 42" stroke. It had a capacity of 12 cubic feet of water per second or 8 million gallons per day, with the engine flywheel making 67 revolutions per minute.[76] In November 1893 this system was reported to have been in constant operation from the time the plant opened.[77] The engine was supplied with steam by a Whitney horizontal return-tube boiler, 72" in diameter, fueled by mesquite wood. A one-year test showed that to lift 8 million gallons of water 80' in 24 hours required 10 cords of mesquite wood, which could be purchased at the railroad station for $3.50 per cord, making the cost of fuel $4.38 to raise one million gallons up to the Mesa.[78]

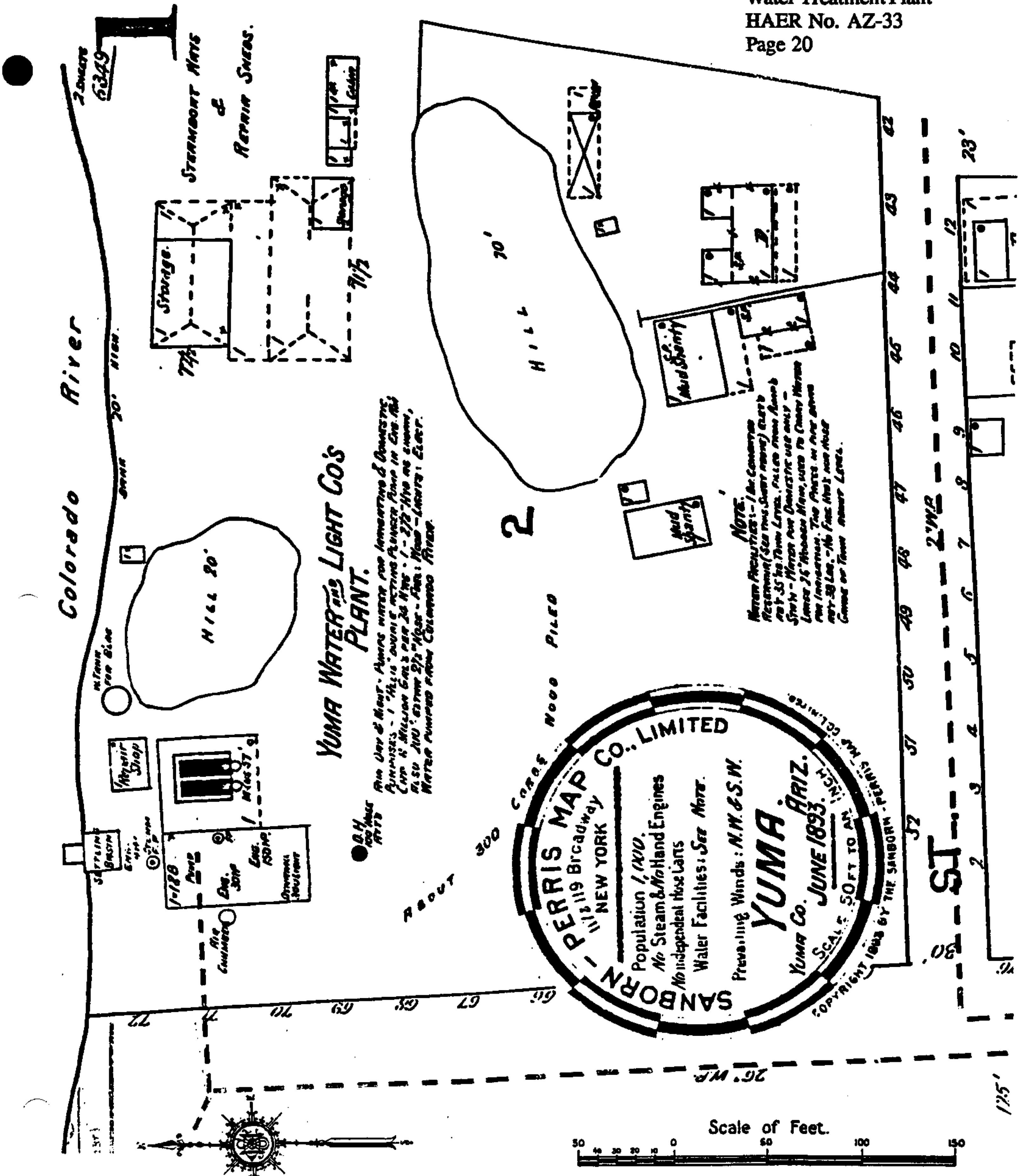

FIGURE 9. SANBORN MAP, YUMA, ARIZ., JUNE 1893.

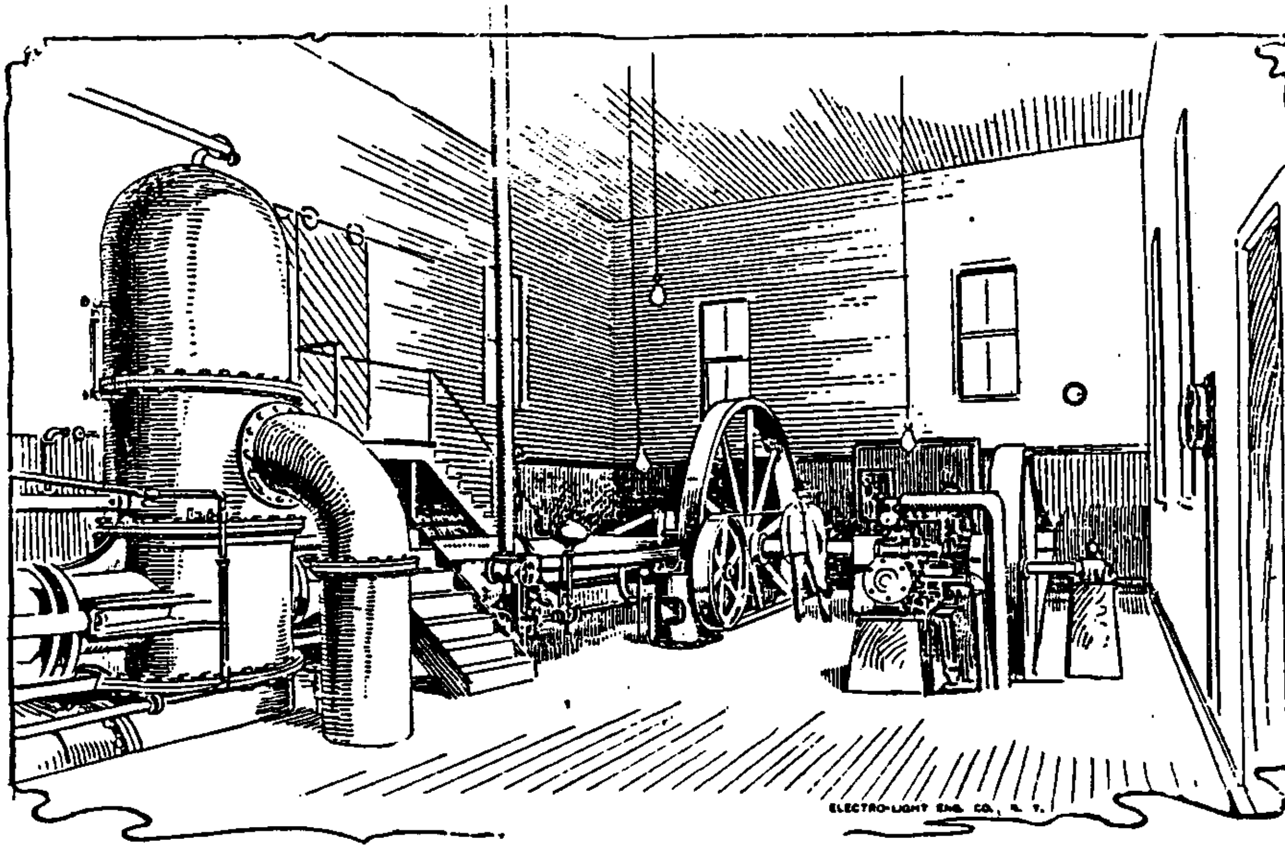

FIGURE 10. HISTORIC DRAWING OF YUMA PUMPING PLANT.[79]

On March 1, 1893, Blaisdell posted a claim for water rights at the point to be the "intake" through which water was to be diverted to the Yuma Water and Light Company pumping works. The claim states that it was posted on the east [*sic*] bank of the Colorado River in Lot 4, of Block 2 of White's Official Survey of the Village of Yuma.[80]

When consumers first began purchasing domestic water in Yuma, they were concerned with water clarification only. The most practical and economical way to reduce turbidity in water was to put it in a container and allow it to settle, just as the early Yuma settlers had done in their whiskey barrels. This was the method adopted on a large scale in 1892 by the Yuma Water and Light Company. The company provided consumers with two types of water: settled, which was comparatively clear, and unsettled, which was muddy and used only for lawn watering and farm irrigation. An 1892 schedule lists monthly prices for settled water:

Single family tenement	$2.00
Bath tubs (public)	$3.00
Bakeries, each 25 bbls. flour	$2.00
Stables, each horse	$1.00

Horse trough on sidewalk	$4.00
Hotels & Taverns, each bed	$0.15
Saloon, Groceries, Etc.	$4.00
Water Closets (public), ea.	$1.50
Water Closets (private), ea.	$0.70
Fire Plugs, ea.	$5.00 [81]

Blaisdell was also granted a franchise on September 5, 1892, to construct and maintain a public street, which the town could not afford to build, along the route of the water main. The street led from the business district to his development, Blaisdell Heights, on the Mesa. Blaisdell had orange, pepper, and palm trees planted along it, and taps were placed in the main specifically for watering the trees. Blaisdell's efforts are remembered today by the street's name, "Orange Avenue."[82]

Settled and unsettled water were delivered by separate mains. The lines went to Madison Avenue and then south to Orange Avenue, then southwest to 3rd Avenue, where they again turned south and continued on to between 8th and 9th streets. There they cut diagonally southwest to 4th Avenue and continued south to the reservoir. As late as 1919 the two lines were still in place, but only the pipe carrying clear water was then in use.[83]

In 1900 a severe fire on North Main Street destroyed a large portion of the business district and almost reached the water plant. It did destroy the mesquite wood, which was stockpiled as fuel for the boilers. At the time there were only four fire hydrants, all privately owned. This fire brought attention to the inadequacy of the system. The new mayor at that time pressed for municipal ownership of the water system, promising better fire protection, but voters defeated the proposal by a 3-to-1 margin. By installing two Dean Underwriter steam pumps with a capacity of 750 gallons per minute each,[84] Blaisdell met the requirements of the Board of Fire Underwriters[85] and achieved sufficient pressure to install more fire hydrants. A new 8" cast iron main was laid to Madison Avenue and south along Madison Avenue to 4th Street, and a 6" main was laid on Orange to 3rd Avenue. New fire hydrants were installed along the lines.[86]

Blaisdell organized the Yuma Telephone Exchange in 1900. The employees served as both switchboard and fire-signal operators. When a call came in reporting a fire, the operator would throw a switch that blew the fire whistle. The exchange was originally located in the Cotter Building on 2nd Street between Main Street and Madison Avenue. (The building no longer exists.) Initially a one-position switchboard served the company's 150 subscribers. [87]

As mentioned earlier, the period between 1890 and 1900 was marked by significant advances in water purification technology. These advances led to demands by the Yuma water users for higher quality water and, in turn, to Blaisdell's efforts to supply his customers with filtered water.

In 1903 the first filtration system at Yuma was constructed. It consisted of a rudimentary sand filter encased in a large wooden box and was located immediately east of the powerhouse. On this filter Blaisdell conducted experiments that led to the invention of the Blaisdell Slow Sand Filter Washing Machine, which he had fabricated in Los Angeles.

BLAISDELL SLOW SAND FILTER WASHING MACHINE

Many prominent engineers came to Yuma to observe Blaisdell's new filter cleaning process.[88] Between 1903 and 1904 Blaisdell obtained at least seven patents on variations of his machine, and in 1909 an article in the Christmas Edition of the *Yuma Daily Examiner* noted that it was in use at Philadelphia, Pittsburgh, and Wilmington and was to be incorporated at the Croton water plant in the city of New York (see Field Records for patents).

Sand filters were initially cleaned by a labor-intensive method. The March 12, 1908, *Engineering News* described the process;

> This method consists, as is well known, of drawing off the water from the sand surface of the filter to be cleaned, scraping off a thin layer of sand from this surface, transporting this sand to sand washers outside the area of the filter, restoring the water level in the filters, and then re-starting at slow rates, which are continued until the filter is again ripened enough to run at normal rates.
>
> The operations of sand scraping and transportation require a large number of laborers and it is desirable that they be employed during working daylight hours; all of the operations occupy from three to five days' time. During this period the filter is performing no useful work of filtering the water and in addition other filters must be provided to keep up the nominal supply. These two conditions operating together require that there shall be a very long period between cleanings: the first, in order that a delay of twelve hours to obtain daylight working hours will not affect the operation of the plant; the second, so that the percentage of the time the filter is out of service to the operation time will not require the construction of a large number of reserve filters. . . .
>
> The progress of the improvement of the slow sand filter has been, therefore, very seriously retarded by the prevalent method of cleaning. A method of cleaning which would keep the filter out of service only and hour or so and would do this work with only one or two operatives, working any hour of the day or night, would make possible many other improvements; such, for instance, as using sand of an effective size proportioned to the work it has to do in removing turbidity and bacteria and not according to the length of the run between cleanings, and, most important of all allow higher rates and a consequent reduction in first cost of construction.
>
> A rapid method of cleaning slow sand filters, such as has just been outlined as necessary for high rates, is furnished by the Blaisdell filter sand washing machine, which has been thoroughly tested under the supervision of the writer, during the past six months, by authority of the city of New York.
>
> Such a machine has already been in operation at Yuma, Ariz., for four or more years, on a slow sand filter, clarifying Colorado River water, having an average turbidity of over 2,000 at a rate of 3,000,000 gals. per acre per day, through sand having an effective size of 0.13 mm., without the use of any coagulants, at a very small maintenance cost and with satisfactory results. . . .
>
> By using a much finer sand than is now the case, much assistance would be afforded toward securing any degree of removal of bacteria or turbidity at any practical rate at the expense of shorter periods between cleanings, but this cleaning is so rapid that the short yield is no longer an element in the problem.

> With further experience, it is the opinion of the writer, that much higher rates than 10,000,000 gals. per acre may prove successful, with a corresponding reduction in first cost of construction, thus bringing filtration within the means of many communities now holding back on account of cost.[89]

The prototype Blaisdell filter washing machine at Yuma is virtually intact, although it has not been used since circa 1954. The machine consists of a gantry crane that travels on steel tracks mounted on top of the walls of the rectangular filtering reservoirs (HAER photographs AZ-33-A-1 through AZ-33-A-5). This crane supports the entire machine including the most significant portion, the washing chamber (HAER photograph AZ-33-A-6 and Field Records photograph 3). The washing chamber is a steel "box" about 4′ square and 2′ deep, which contains a 4′ rotating circular washing unit. The washing unit within the box consists of a hollow axle and hollow head from which hollow teeth project downward into the sand at any desired depth from 8″ to 18″.[90]

In operation, the washing chamber was lowered under the water in the filter to the surface of the sand and held in that position by electric machinery on the operating platform above. As the chamber traveled across the surface of the sand filter beds, the hollow head and hollow teeth of the washing unit revolved slowly, stirring the surface of the sand mechanically. Water under pressure of 10 to 20 pounds per square inch was introduced through the axle to the hollow teeth and in fine jets stirred the sand by passing directly into it.[91]

Two suction pumps connected with the top of the chamber then drew away slightly more water than was supplied through the axle to the teeth. They drew away the dirt and impurities that were stirred and washed from the sand and discharged them through a flexible hose into a sheet-metal-lined wood sewer trough at the side of the gantry (HAER photograph AZ-33-A-3 and Field Records photograph 4). Because a small amount of water was drawn into the chamber from under its edges, none of the dirty water was allowed to escape into the filter reservoir itself.[92] As the gantry moved along the track, the sheet metal trough moved with it and discharged the waste water through a sheet metal spout into a concrete gutter that paralleled the filter reservoirs (Field Records photograph 5). From the gutter, the waste water was returned to the river through a sump at the west end of Filtering Reservoir No. 1 (Field Records photograph 6).

The operator sat in a small operator's cabinet with electric controls for all the machinery (Field Records photograph 7). By these controls, the box could be raised or lowered and the platform could be moved back and forth across the filter, while the entire gantry crane could be moved up and down the long rectangular filter beds. In later applications of larger size, such as the plant at Wilmington, the box could be raised above the level of the filter bed wall and the entire machine moved by transfer crane to a parallel row of filters.[93]

At Yuma a corrugated steel roof provided shade from the desert sun and protection from rain for the entire platform area with its operator's cabinet, controls, motors, pumps, and other machinery (Field Records photograph 8). Later Blaisdell machines had different configurations but performed essentially the same process. Normally the machine at Yuma required only four or five "runs" up and down a filter to clean it, thus taking a mere 45 minutes to wash one of the filters completely. An electric cutoff mechanism allowed the washing machine to stop automatically at the end of a filter reservoir on occasions when the operator was called away to do other work.[94] (See Field Records photographs 9 through 24 for additional views of the Blaisdell machine.)

The Blaisdell machine gained national acceptance for use in association with slow sand filters during the early years of the twentieth century, after its initial success at the Yuma Water and Light Company. Various modifications of the machine were developed for specific installations ranging from 3 to 40 million gallons per acre daily, on the principle that:

> Increasing the efficiency of the filters by running up the rates of filtration can avail nothing if the cleaning time still stays the same. Thus, if a plant now filtering enough water in 23 days to necessitate cleaning, this taking 2½ days, is so improved that the same amount of water can be treated in say 15 days—with necessarily the same length of time for cleaning, since the same amount of dirt will collect—reserve filters to take care of the water during cleaning of the others will have to be placed to take 10% in the improved system against only 10% in the original. The first cost and the maintenance of this larger system will offset the gain by more rapid filtration.[95]

Filter efficiency was studied by the Board of Water Supply of New York City, and a test filter bed was built at Jerome Park upon which various schemes for cleaning the dirty sand were tried. William B. Fuller, who presented a paper in 1908 on the results, noted that the patented Blaisdell process "in use in Yuma and other western plants" was the best that had been tried and could revolutionize the operation of slow sand filters.[96] It is unknown whether a Blaisdell machine was ever installed in New York.

The city of Philadelphia installed a Blaisdell Slow Sand Filter Washing Machine at its Belmont Filtration Plant in about 1903. It was not used on slow sand filters, but instead on a preliminary filter bed in response to a specific problem. Water was to be clarified by passing horizontally through a coke filter, upwards through a sponge filter and then downwards through a filter made of coke breeze ranging from ⅛" to ¼" in diameter, at a rate of 40 million gallons per acre per day.[97] The first two preliminary filters did not reduce the turbidity of the water as planned. With higher levels of sediment to remove, the coke breeze filter could not handle the plant's large volume of water unless continuously cleaned. A Blaisdell machine was installed on the coke breeze filter to achieve this end.[98]

In the *Engineering Record* of May 4, 1907, a description was given of the waterworks at Wilmington, Delaware, which consisted, in its more important parts, of a pumping station, a preliminary filtration plant, and a sedimentation reservoir. The original designs for the purification plant, prepared by Theodore A. Leisen, chief engineer of the water department, called for water to pass from preliminary filters through slow sand beds and then to distributing mains, but the construction of the entire system was not undertaken when it was designed in 1905. For the first two years the only purification of the raw water was that effected by the preliminary filters and sedimentation reservoir. In 1907, however, funds became available, and 6 slow sand units, a Blaisdell Slow Sand Filter Washing Machine, a control house, and a filtered water reservoir were constructed.

The lower course of the filtering material was 14" of crushed stone and graded gravel, on which rested a layer of sand 24" thick. The sand was dredged from the Delaware River and had an effective size of 0.24 mm and a uniformity coefficient of 2.2. The head of water on the sand was 4½'. The filter beds measured 363' x 42' and were built in this unusual shape to permit the use of the Blaisdell machine. They operated at a rate of 5 million gallons per acre daily when installed, although they were designed to handle 8 million gallons if needed.[99]

Wilmington had serious problems with trapped air in the filter beds, creating a negative head and preventing the passage of water through the beds. The filters were built indoors and were supported over the clean water reservoir. Leaks in the vaulted structure between the filters and reservoir allowed air to pass upward into the filter. In 1912 temperatures dropped to -5°F. in early January and remained below freezing until the middle of February. Heavy ice formed on the filters making it impossible to use the Blaisdell machine. The filters became completely saturated with air and the surface of the sand was seriously clogged and compacted by the pressure of water above it. All filtration stopped and could not be resumed until the ice was dynamited off of the beds and the flow reversed to relieve compacting beyond reach of the Blaisdell machine. While the machine generally alleviated situations of clogging and surface compaction by stirring the surface of the sand, this incident with icing probably was one of the reasons for the machine to loose favor among engineers.

Beginning in 1918 the city of El Centro, California, purified Colorado River water, which was high in both turbidity and bacteria, at a rate of about 3 million gallons daily without chemical treatment.

> Yuma discharges the sewage of its 5,000 people into the river 8 miles above the headgates of the Imperial Canal and the water is further contaminated in its course through the canal. By the time it reaches El Centro the turbidity often reaches 5000 parts per million, the bacterial count 28,000 per c.c., and B. coli 10 per cubic cm. . . .

The design for the El Centro plant was prepared, and the construction carried out, by the Blaisdell Filtration Company of Los Angeles.[100]

YUMA WATER AND LIGHT COMPANY AFTER 1903

In 1906 the Yuma Water and Light Company waterworks underwent major improvements. New facilities included two concrete settling reservoirs, each with a capacity of 400,000 gallons, a concrete filtering reservoir with the prototype Blaisdell machine, and a pressure reservoir on Black Hill, also known as Sierra Prieta (Field Records photograph 25). The settling and filtering reservoirs are first seen on the 1911 Sanborn-Perris map (figure 11).

Water was admitted to the treatment plant at the northwest corner of the west reservoir, filling it to capacity and then overflowing into a chamber along the entire width of the reservoir. From this chamber the water was carried by a tile pipe to the bottom of the east reservoir. At the south end of the east reservoir water was drawn off continuously by means of a long perforated pipe suspended by a float. This settled water flowed by gravity to a float cleaner at the southwest corner of the sand filter, which kept the water at a constant level.[101] From the sand filter, clear water was pumped to the pressure reservoir on Black Hill, at an elevation of 120' above, and at a distance of about one mile south of, the plant. The pipe line ran along Madison Avenue. The reservoir, having a capacity of 168,000 gallons, was an elliptical depression 10' deep x 140' x 100', which was blasted out of the native rock, surfaced with cement grout, and roofed.[102] Over the years the topography of Black Hill was modified; traces of the reservoir are still visible (Field Records photograph 26).

On Nov. 1, 1907, a first mortgage was taken out on the Yuma Gas Company as a division of the Yuma Water and Light Company. A gas holding tank with a capacity of 30,000 cubic feet also appears on the 1911 Sanborn map (figure 11) at the north west corner of the intersection of Gila and Jones streets. Additions to the power plant building also appear on this map.

In 1916 flooding of the Gila broke the levee, and water four feet deep ran down the streets of Yuma before emptying into the Colorado, which was also at flood stage. The boilers at the Yuma Water and Light Company plant were partially submerged and the water pumps were under eight feet of water.[103] The flood so heavily damaged the waterworks and power plant that Blaisdell did not undertake their repair.[104] In 1917 the property was sold to the Continental Securities Company, which operated it for eight years as the Yuma Light, Gas & Water Company.[105]

The 1917 Sanborn Map (figure 12) shows that soon after acquiring the facility, the Yuma Light, Gas & Water Company added a second sand filter identical to the first, and constructed a third settling reservoir with a capacity of 800,000 gallons. The original wooden pipes carrying unsettled water, the "muddy water system," had deteriorated and were abandoned. The "clear water system" was extensively repaired to deliver filtered water. A new 10" cast iron water main was installed from the waterworks to the Black Hill reservoir, and other mains were replaced throughout the system.[106] In 1919[107] a third filter bed similar in dimensions and construction to the first two was built, a water softening plant was added, and the gas plant was enlarged (figure 13).

In 1925 the company was sold to Codon Engineering Company, which operated it under the name of Arizona Edison Company until January of 1928, when it became part of a statewide utility merger with the Peoples Light and Power Corporation of New York. In March 1928 an L-shaped settling reservoir with a capacity of one million gallons was built, bringing the waterwork's total capacity to 2.6 million gallons. The L shape was selected to accommodate the 1907 gas holding tank. By 1930 an additional gas holding tank of 150 thousand cubic feet had been added at the southwest corner of the intersection of Jones and Gila streets. Also, another addition was made to the electric power plant building. The addition of a fourth sand filter, longer than the first three, brought the total filter length to 411' and the total area to 10,275 square feet (figure 14).

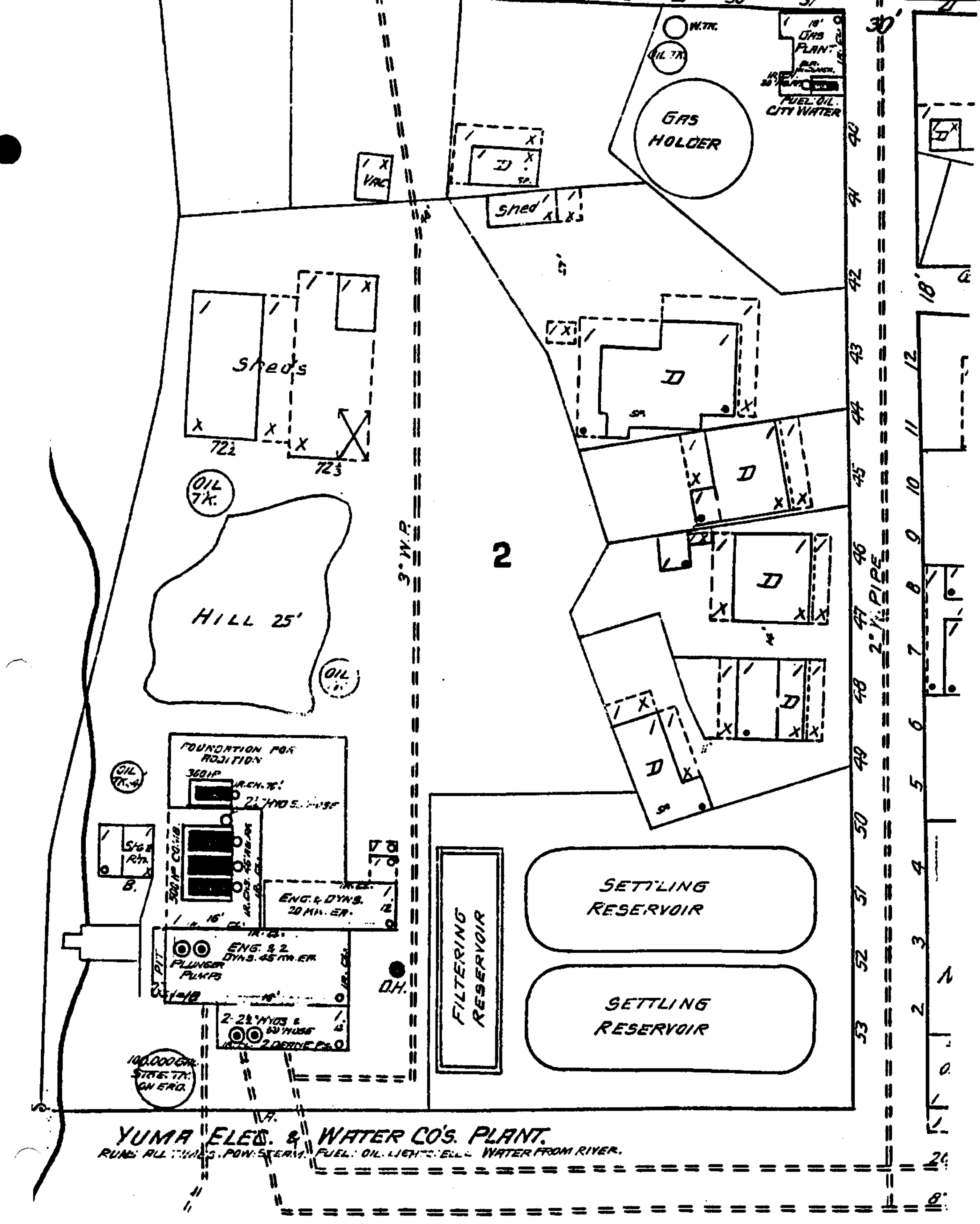

FIGURE 11. SANBORN MAP, YUMA, ARIZ., MAY 1911.

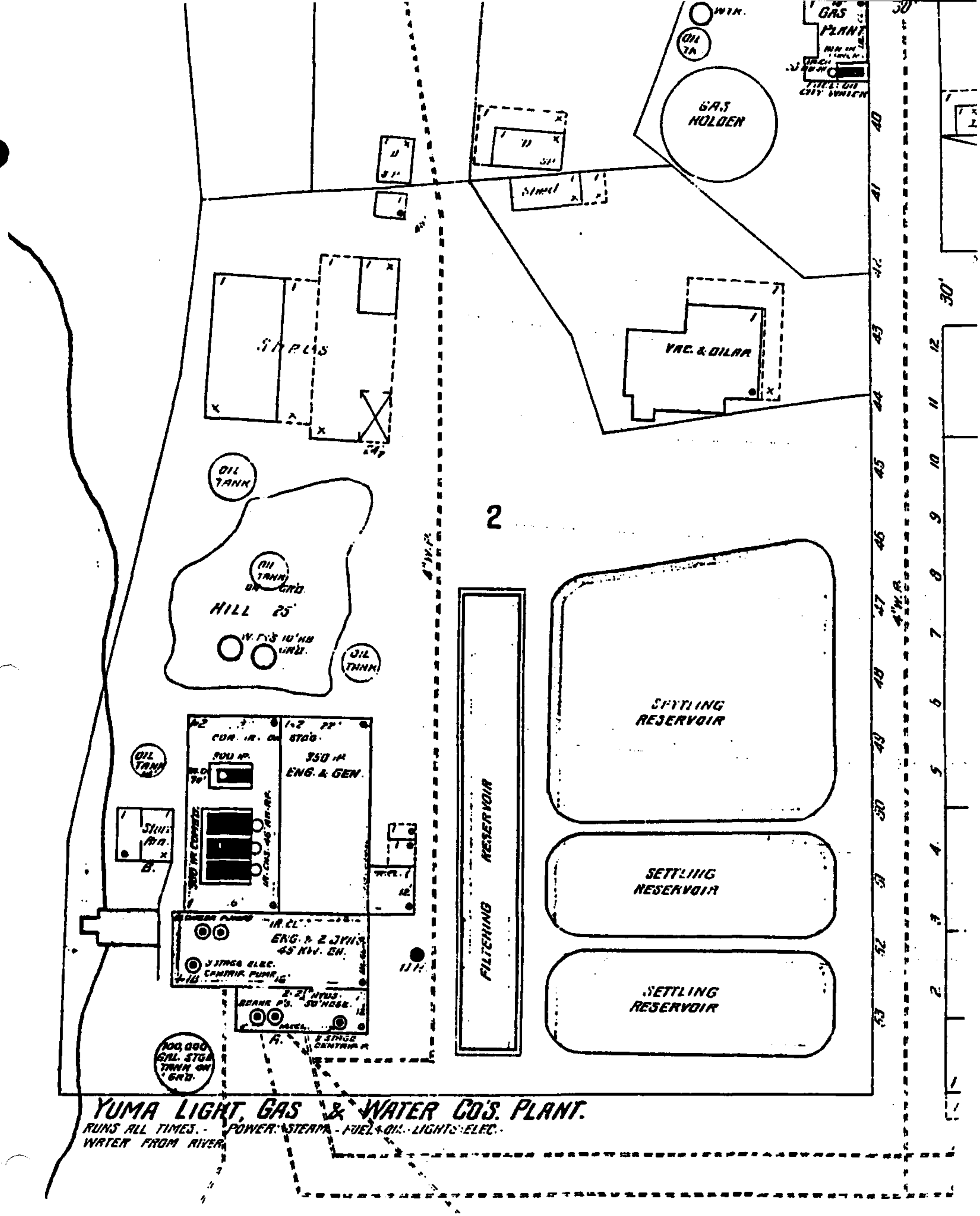

FIGURE 12. SANBORN MAP, YUMA, ARIZ., AUG. 1917.

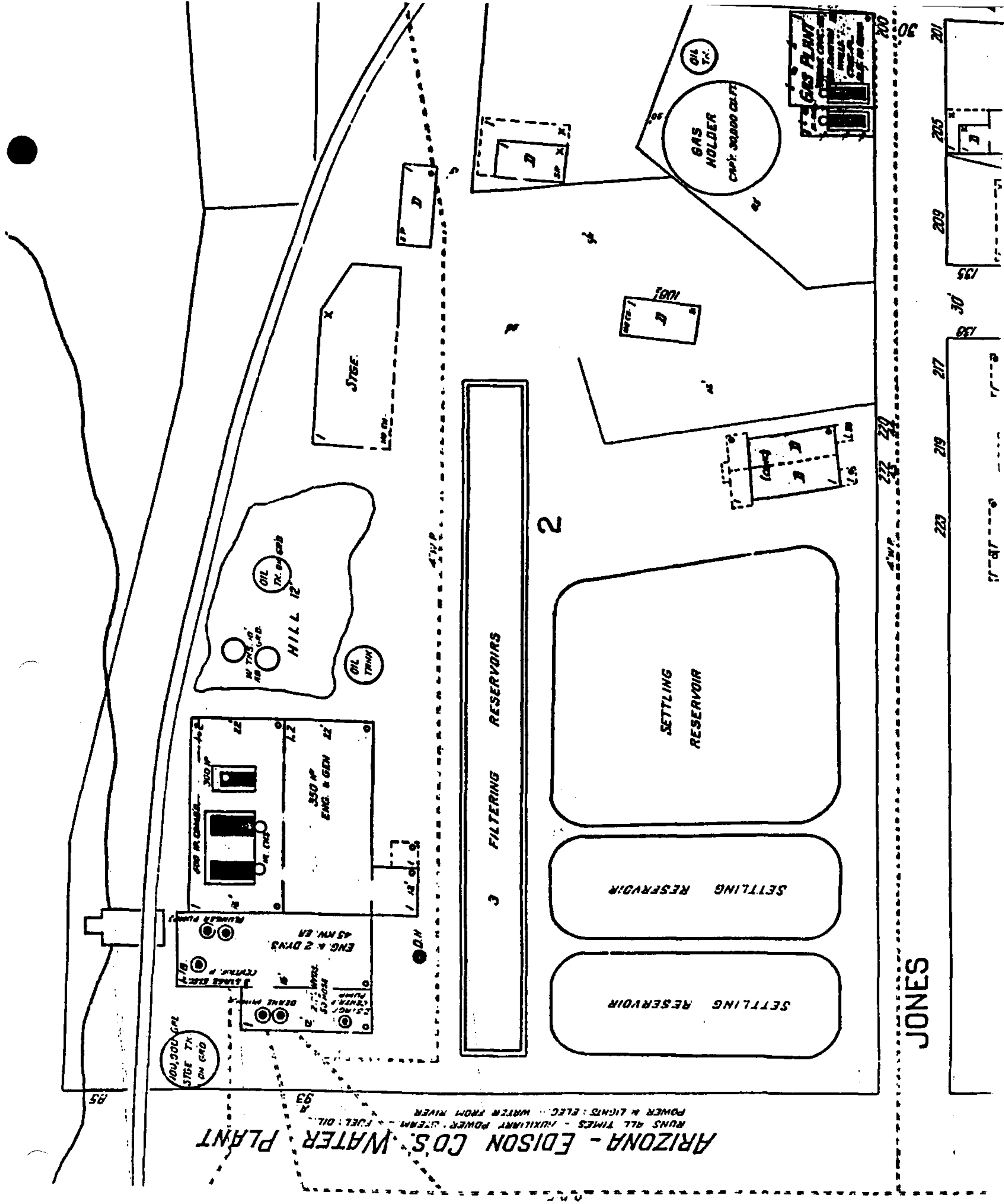

FIGURE 13. SANBORN MAP, YUMA, ARIZ., APRIL 1927.

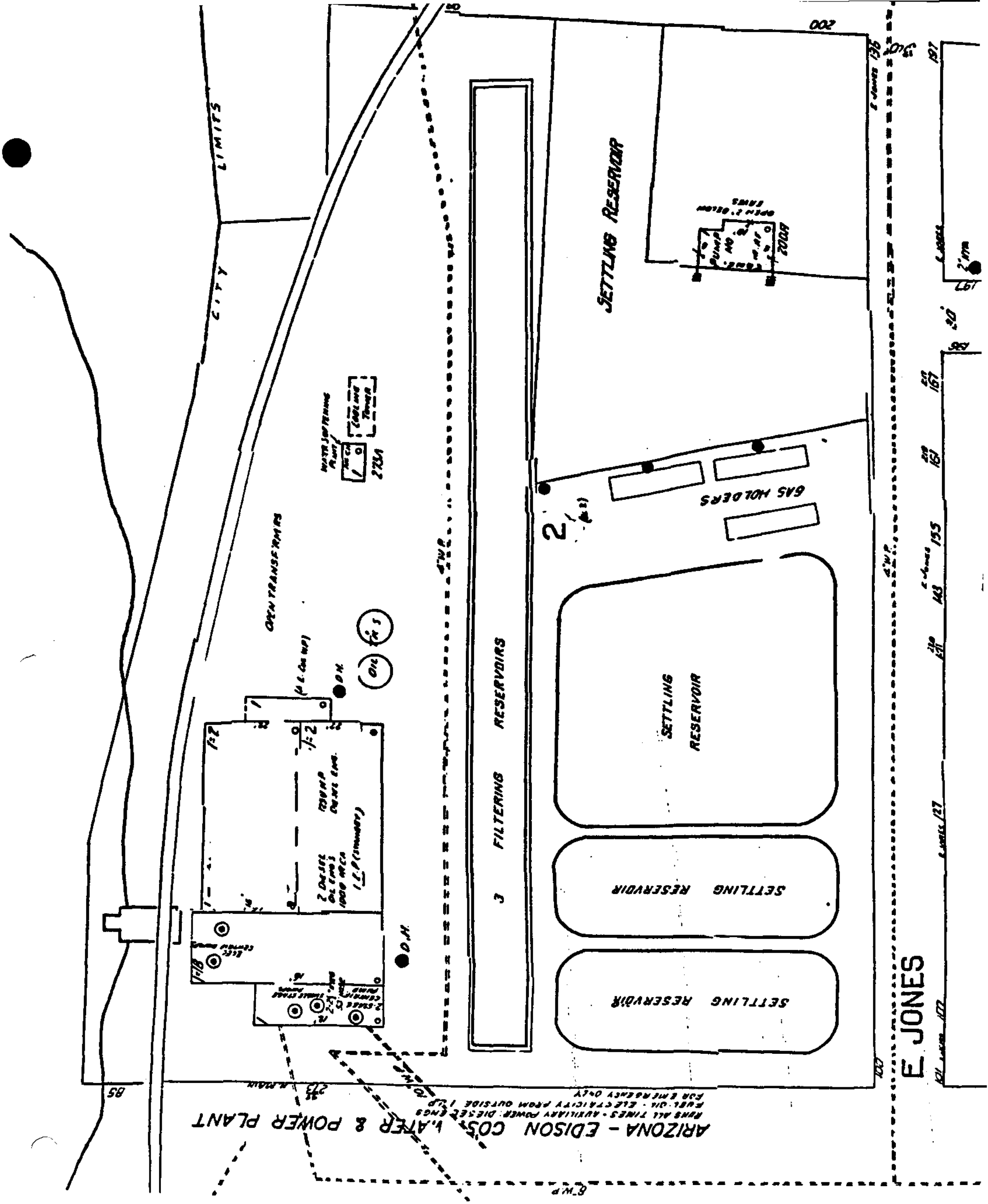

FIGURE 14. SANBORN MAP, YUMA, ARIZ., 1948.

The Peoples Light and Power Corporation was a casualty of the Great Depression, and in January 1932 the company went into receivership. For the next three and a half years very little, if any, money was spent on maintenance or improvement of the system. The company was reorganized on June 25, 1935, as the Arizona Edison Company, Inc., beginning a period of steady growth that continued through World War II.[108] In 1941 voters rejected municipal ownership of the waterworks, as they had in 1900.[109]

Over the ten-year period between 1935 and 1945, a 60% increase in the number of customers brought a 165% increase in winter water demand and a 400% increase in summer demand. Until 1940 demand slowly built from a maximum of 900,000 gallons daily to 2,090,000 gallons. From 1940–1943 it grew to 4 million gallons. The settling reservoirs were operated on a rotating cycle of fill and drawdown, with the length of retention periods varying with the demands on the system. During the winter, 8–10 hours were allowed for settling but during peak summer conditions 2–3 hours was usual. Unsettled water often had to be applied to the filter beds. Either increased capacity or more rapid methods of settling were needed.

A series of tests were undertaken to determine if the settling time could be reduced by the use of a coagulant. The best results were obtained using 143 pounds of aluminum sulfate per million gallons of water treated, or 17 parts per million. With a 15 minute period of flocculation following the addition of the coagulant, turbidity could be reduced 91% with only an hour of settling. On these grounds, the settling reservoirs were modified to allow chemical treatment.

Construction of the modifications began on February 15, 1944, and was completed on June 1, 1944, at a cost of $20,000. A capacity of 6 million gallons daily, 2½ times the 1943 capacity was achieved. Settling Reservoir No. 1 was used as a presedimentation basin where most heavy silt was deposited (HAER photograph AZ-33-9). Settling Reservoir No. 2 was reconstructed with vertical end walls to accommodate four rows of flocculators 6′-6″ in diameter. A chemical flash-mixer was installed in the dividing wall between the two reservoirs. The south half of Settling Reservoir No. 2 was modified for equipment storage. Settling Reservoir No. 3 served as a final sedimentation basin from which the water flowed into the filters. Filtered water was collected in four small clear water wells, one serving each of the four filters, connected to a common suction line supplying four De Laval high-service centrifugal pumps. Chlorine was applied through the suction line immediately ahead of the pumps. After water flowed through the presettling reservoir and immediately before it came to the flash-mixer, aluminum sulfate was added. From the mixer, water entered the flocculation reservoir and then passed through baffle walls into the final sedimentation basin, Settling Reservoir No. 3. From there it flowed by gravity to the filters. Settling Reservoir No. 4 was not disturbed at this time and was the only basin available to settle raw water during the construction of the modifications.

By 1947 both gas holding tanks and the gas plant building had been replaced with a butane plant located between Settling Reservoirs No. 3 and No. 4. The power plant building underwent major changes to incorporate a high service pump, a garage, a superintendent's office, and a diesel-electric generator. A spur was run off the Southern Pacific line, and an electric substation stood to the north of the line, two fuel-oil tanks and a cooling tower to the south. A service road ran between the filters and the electric plant.

Between 1947 and 1949 two rapid mechanical sand filters and a wash-water storage reservoir replaced Filtering Reservoir No. 4. The new mechanical filters were cleaned by backwashing. After all the slow sand filters had been replaced with mechanical filters, the Blaisdell machine became obsolete and was abandoned. It was last used in about 1954. At that time it was probably the last of its kind in use. Today it is likely the last one in existence.

The 1959 Sanborn map shows a reservoir and chlorinating room inside the L of Settling Reservoir No. 4. It also notes that the slow sand filters, although still present, are "not used" (figure 15).

By 1972 part of Settling Reservoir No. 4 had been given over to wash water storage for the rapid mechanical filters. Two more rapid filters were installed inside the L of this basin along with chlorine storage and application structures. Chlorine was applied to the water at three places: at the raw water inlet to the presettling basin, at the diversion to the rapid sand filters, and at the filtered water effluent line in the chlorine application pit. The rapid filters had a total capacity of 13.6 million gallons daily. A large part of the power plant structure had been demolished and what remained was abandoned. A 500,000-gallon, underground, filtered-water reservoir was installed south of Jones Street and flocculation and sedimentation basins were installed between the railroad tracks and the river.

Sometime between 1972 and 1982 Filtering Reservoir No. 3 was demolished. By 1982 flocculation and sedimentation basins were located at the northwest corner of Main and Jones streets. South of Jones Street an office building, a control building, high service pumps, an electric substation, a chemical building, a filter complex, and an electric equipment building were established.

Electric power has been transmitted into the area by Arizona Public Service since 1972, and the waterworks has been owned and operated by the city of Yuma since 1966.

YUMA MAIN STREET WATER TREATMENT PLANT PRIOR TO 1993 MODIFICATION

IDENTIFICATION OF COMPONENTS

In August 1993, before demolition began, the plant proper consisted of numerous components constructed at different times. Some of these components were more than 50 years old; others were of more recent origins and, consequently, were noncontributory elements (figures 16 and 17). Nonhistoric features, most of which were constructed after about 1954, and a circa 1917-1927 house are located immediately south of Jones Street between Main and Gila streets, placing them outside the Yuma Crossing National Historic Landmark. The house has been severely modified and is now used as the Control Building. The historic components of the plant were all within the landmark.

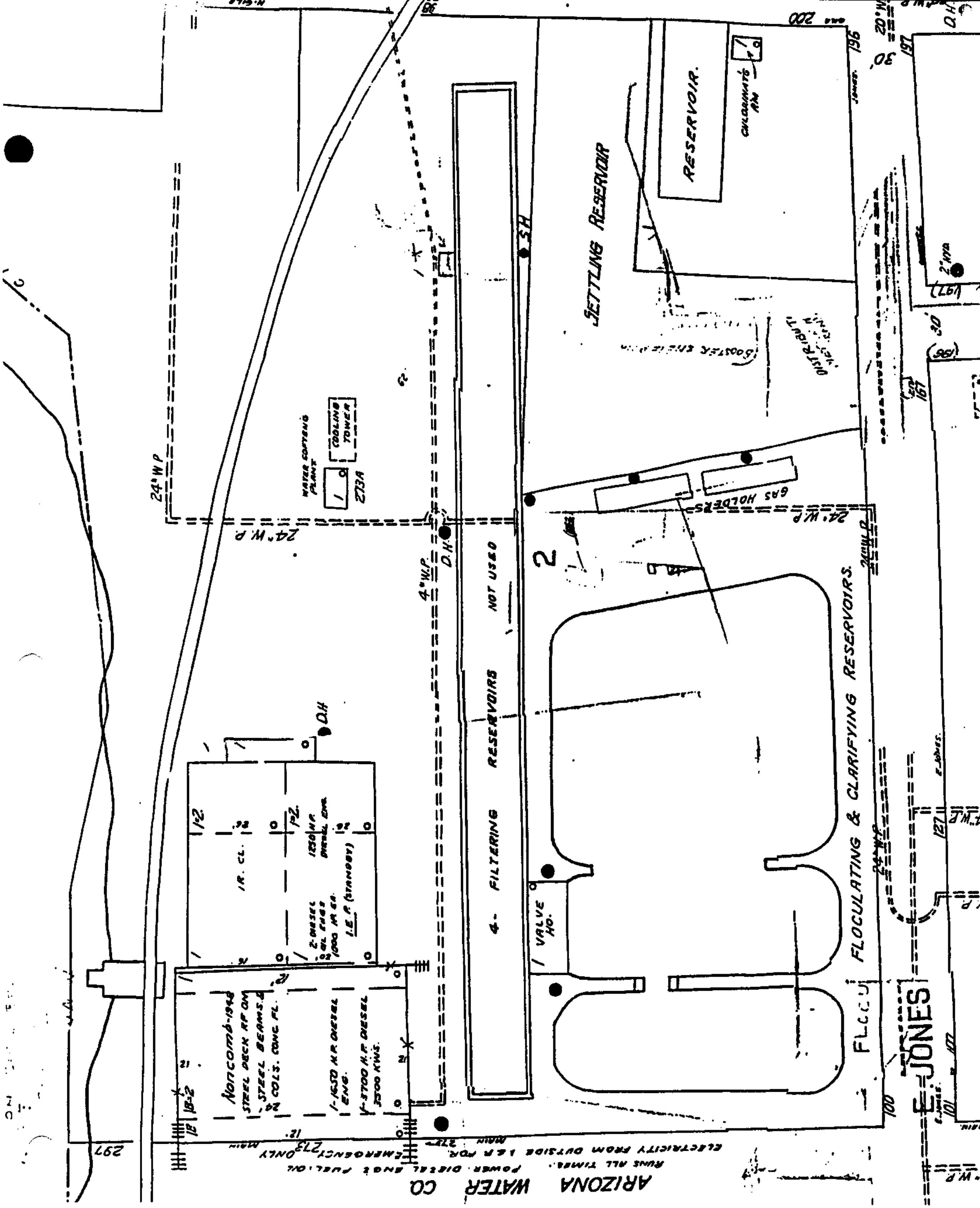

FIGURE 15. SANBORN MAP, YUMA, ARIZ., 1959.

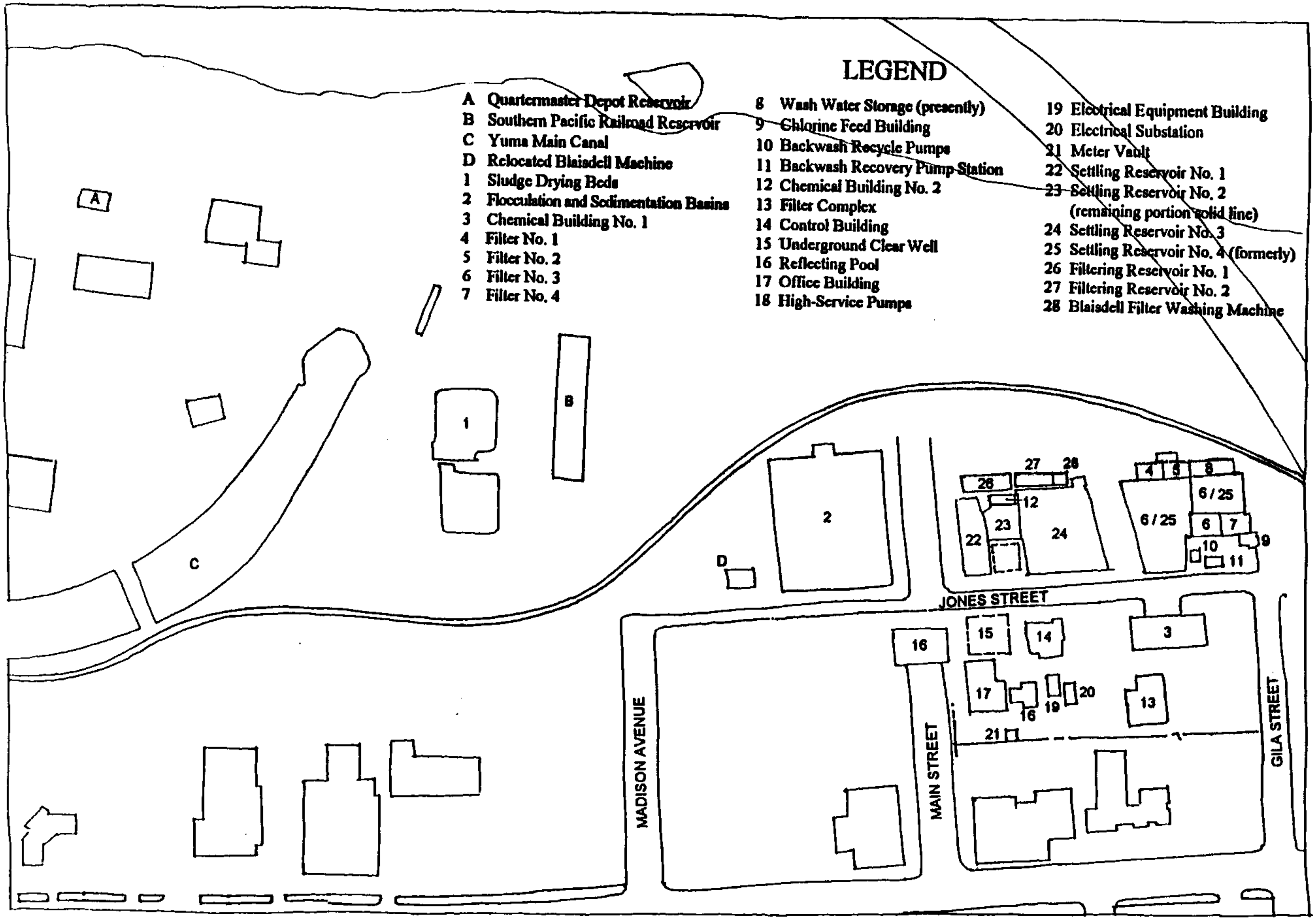

FIGURE 16. KEY AND LEGEND FOR FIGURE 17.

FIGURE 17. DIMENSION-CONTROLLED AERIAL PHOTOGRAPHIC MAP. SCALE: 1" = 200'
(CONTACT PRINT AND NEGATIVE [AZ-33-12] ARE INCLUDED WITH PHOTOGRAPHS.)

As previously noted, one element of the plant, the Blaisdell Slow Sand Filter Washing Machine, is individually listed on the National Register of Historic Places (NRHP) for its significance to "industry" and "invention" in the early years to the twentieth century. In September 1993 the machine was relocated to a nearby site outside the water treatment plant boundary but within the Yuma Crossing National Historic Landmark, to accommodate expansion of the water treatment plant. One slow sand filter reservoir was reconstructed (simulated) with an abbreviated length at the new location to support the Blaisdell machine (Field Records photograph 27).

Components Less Than 50 Years Old

Sludge Drying Beds
Flocculation and Sedimentation Basins
Chemical Building No. 1
Filter No. 1
Filter No. 2
Filter No. 3
Filter No. 4
Wash Water Storage Reservoir
Chlorine Feed Building
Backwash Recycle Pumps
Backwash Recovery Pump Station
Chemical Building No. 2
Filter Complex
Control Building
Underground Clear Well
Reflecting Pool
Office Building
High-Service Pumps
Electrical Equipment Building
Electrical Substation
Meter Vault

The above-listed elements, constructed after 1943, were determined to be ineligible for listing on the NRHP because they did not meet the criterion of age and, therefore, are not further discussed in this document.

Components More Than 50 Years Old

Settling Reservoir No. 1	Circa 1902-1906
Settling Reservoir No. 2	Circa 1902-1906
Settling Reservoir No. 3	Circa 1917
Settling Reservoir No. 4	Circa 1928
Filtering Reservoir No. 1	Circa 1902-1906
Filtering Reservoir No. 2	Circa 1917
Blaisdell Slow Sand Filter Washing Machine	Circa 1902-1906

The above-listed elements, constructed before 1943, were determined to be eligible for listing on the National Register of Historic Places because of their age and significance to the history of water treatment in the United States. Although these components were largely intact at the time this documentation was prepared, they had, with the exception of Settling Reservoir No. 4, been abandoned since circa 1954 and were in a state of disrepair. Settling Reservoir No. 4 has remained in use, first as a settling basin and most recently as a filter wash-water storage reservoir. While all the other historic components were demolished in 1993 to accommodate new treatment facilities, Settling Reservoir No. 4 was retained in service as a filter wash-water storage reservoir.

PRE-1943 PLANT COMPONENTS

Settling Reservoir No. 1 (figures 16 and 17) was approximately 118′ long (north-south) x 44′ wide at the top. The sides taped inwardly to bottom dimensions of approximately 100′ x 26′. The depth was approximately 8′, and the capacity is reported to have been 400,000 gallons (HAER photographs AZ-33-9, AZ-33-11, and AZ-33-12). The reservoir was constructed more or less on grade with earth berms faced with rock and was lined with concrete approximately 4″ thick (HAER photographs AZ-33-7, AZ-33-10, and AZ-33-15). The concrete was reinforced with woven wire fencing which was laid into the sides and extended approximately 20″ along the bottom. For its original use as a settling basin, the bottom was filled with gravel about 12″ deep under 2½″ of sand. Water about 5′ deep stood in the basin to settle. An inlet pipe was found at the northwest corner of the basin. In 1944 the reservoir was converted into a presedimentation basin by the installation of wood baffles (HAER photograph AZ-33-12).

Settling Reservoir No. 2 (figures 16 and 17) was, until 1944, identical to Settling Reservoir No. 1. In 1944 it was divided into two segments with an east-west concrete wall, and the north portion was converted into a flocculation reservoir. Concrete columns that were used to support the flocculation equipment were present; the equipment had disappeared (HAER photograph AZ-33-16). See HAER photograph AZ-33-5 for 1943 conditions.

Settling Reservoir No. 3 (figures 16 and 17) was similar in construction to No. 1 and No. 2 reservoirs but had a trapezoidal surface area measuring approximately 118′ (north-south) x 95′ on the north side and 115′ on the south side. A semicircular skimming trough, added in 1944, ran along the east and south sides of the reservoir. This trough was made from sections of 36″-diameter cement-asbestos pipe cut in half lengthwise and was supported on concrete piers. At the northwest corner of the reservoir there was a group of concrete columns that supported spray equipment that reportedly aerated the water. This feature, most likely, was also installed in 1949 (HAER photographs AZ-33-8 and AZ-33-10 and Field Records photographs 28 and 29).

Settling Reservoir No. 4 (figures 16 and 17) is L shaped with the short leg running north-south and the long leg running east-west. The north-south leg measures approximately 135′ long and the east-west leg 185′ long. The surface area of the reservoir is approximately 9,200 square feet. The reservoir is constructed on grade with lumber-formed concrete. The vertical walls are 10″ thick and are reinforced with concrete pilasters (Field Records photograph 30). The bottom is also concrete. A number of inlets, some capped and others connected to piping, are located in the walls. Various outlets are found in the bottom.

Filtering Reservoirs (figures 16 and 17). The two remaining filtering reservoirs, although constructed at different times, appeared to be identical (HAER photograph AZ-33-10). The filters were located end-to-end and each was approximately 25′ wide (north-south) x 93′ long (east-west). They were constructed with concrete walls that measured 8″ thick at their tops. The walls sloped inward to a thickness of 15″ at the base. A grid of ¼″ square, twisted bars was used to reinforce the walls at spacings of 12″ horizontally and 24″ vertically (Field Records photograph 31). Similar bars, spaced at 24″ across the width and 12″ across the length, reinforced the 4″-thick concrete floor. Water was fed into the filtering reservoirs by a system of pipes and valves from the settling reservoirs. Underdrains of 6″ tile converge in a collecting pocket of concrete, from which a 6″ pipe carried water to a 36″ x 8′ tank and from there to the pumps. The filtering reservoirs were filled with a mixture of sand and gravel. Narrow-gauge railroad rails, upon which the Blaisdell Slow Sand Filter Washing Machine traversed the length of the filters, were attached to the tops of the east-west walls (Field Records photograph 5). A concrete gutter ran along the north side of the slow sand filters to collect wash water from the Blaisdell machine for return to the river. Two other filtering reservoirs were connected to the east end of the existing reservoirs but they were demolished after 1954.

Miscellaneous Historic Components

The demolition of the historic settling and filtering reservoirs was monitored to determine their functional relationships. Unfortunately, much of the below-ground piping connecting the various elements had been modified or otherwise disturbed over the years, and, consequently, it was not possible to trace the original piping with any degree of certainty. Nevertheless, sufficient remnants of the original piping remained *in situ* to determine, in a general way, the probable operation of the pre-1943 plant.

Operation of the Pre-1943 Plant

Initially raw water was pumped directly from a river intake into Settling Reservoirs Nos. 1 and 2. Sometime later, probably after Settling Reservoir No. 3 was constructed, raw water was drawn from the Yuma Main Canal at the siphon discharge (Field Record photograph 32) and piped to Settling Reservoirs Nos. 1, 2, and 3. The supply piping was located in the earth between the north walls of the settling reservoirs and the south walls of the filtering reservoirs. Settling Reservoir No. 4 was supplied with water from Settling Reservoir No. 3 by an above-grade pipe (Field Records photograph 30). Flow of the raw water entering the settling reservoirs was controlled by a system of valves that permitted the reservoirs to be filled independently of each other in any combination (Field Records photograph 33). Water entered the reservoirs in the north walls at about mid height. Operating rods extended from the valve stems to above the ground (or water) surface. Water was allowed to settle, probably 4 to 8 hours depending on the season, before it was fed by gravity into the filters. Apparently water from any settling reservoir could be fed into any filtering reservoir. Additionally, the filtering reservoirs were connected by weirs in the tops of the walls separating the reservoirs, thereby equalizing the depth of water over the filter sand. The flow of settled water into the filtering reservoirs was controlled by valves, allowing water from one or more settling reservoirs to enter the filtering reservoirs (Field Records photograph 34). Apparently the valving allowed one or more filtering reservoirs to remain dry. After flowing through the filters (from top to bottom) filtered water was collected at the bottom of the filters and piped into a main that ran parallel to, and a few feet north of, the north walls of the filters. The water was then pumped through the distribution system to the pressure reservoir on Black Hill, from where it was delivered to the company's customers. A tank was still present on the hill in 1982 (Field Records photograph 2).

SIGNIFICANCE OF YUMA MAIN STREET WATER TREATMENT PLANT

The site of the water treatment plant is the location of many significant events, activities, and no-longer-extant buildings and structures that predate the plant. The site possesses historical, cultural, and archaeological values regardless of the historical significance of the treatment plant. The importance of the site relative to events not associated with the plant resulted in the site's inclusion within the boundary of Yuma Crossing National Historic Landmark. (See National Register nomination form, Yuma Crossing and Associated Sites, 1966.) Nevertheless, the water treatment plant itself is important to American engineering history.

The period between 1890 and 1900 was marked by significant advances in water treatment technology. In 1890 there were a number of small plants in the United States, but little information is available about their construction or operation. These early waterworks were intended to accomplish water clarification only, because at that time the transmission of disease by water was not widely understood. This was the situation in 1892, when the *Arizona Sentinel* said of the Yuma Light and Water Company's first facilities:

> This grand project will be of great benefit to Yuma, and will do more towards building up the place, than any enterprise so far ever undertaken in the town. Mr. [Hiram W.] Blaisdell deserves great credit for his persistent and successful efforts to carry out this great enterprise and will have the hearty cooperation of everyone who desires to see the prosperity of Yuma and its surrounding country.[110]

By the turn of the century it had been scientifically proven that slow sand filtration, although perfected long before bacteria were known to exist, was as efficient in removing microorganisms as it was in clarifying water, which had been its original purpose. Of the 22 slow sand filters in operation at the end of the year 1900, most, and perhaps all, were located east of the Mississippi River.

In 1903 the Yuma Light and Water Company constructed slow sand filters, making Yuma one of the first communities in the West to provide its citizens with water purified by settling and filtration. The principal elements of this early filtration plant remained largely intact (although abandoned since circa 1954) until they were demolished in 1993, providing a rare opportunity to gain knowledge of early American waterworks utilizing filtration.

Additionally, at the turn of the century, Hiram W. Blaisdell, who was already engaged in improving his waterworks and light plant, serving as a director of mining and irrigation companies, and developing a citrus industry in Yuma, began experimenting with machinery for washing sand filter beds. It was his invention of the filter washing machine that made slow sand filtration faster, more efficient, and more economical, thereby fostering its widespread use throughout the country. Blaisdell went on to achieve national recognition for his invention.

The prototype Blaisdell Slow Sand Filter Washing Machine remained in service at the Yuma waterworks until circa 1954, when its use was discontinued. Fortunately, the machine was still in very good repair when it was moved, as a preservation measure, to a nearby interpretive site in the Yuma Crossing National Historic Landmark in 1993, where it was installed on a reconstructed segment of the filtering reservoir. Although the relocation of the machine did not adversely affect its historic significance, the machine's integrity was diminished by its separation from the original settling reservoirs, which were demolished to accommodate new treatment facilities. Nevertheless, the Blaisdell invention remains a noteworthy example of American engineering ingenuity on the Western frontier at the turn of the century and retains its eligibility for listing on the National Register of Historic Places.

ENDNOTES

1. Moses Nelson Baker, *The Quest For Pure Water*, (New York: The American Water Works Association, Inc., 1948), 125.

2. Ibid., 133.

3. Ibid., 1.

4. Ibid., 3.

5. Ibid., 2.

6. Ibid., 9.

7. Ibid., 15.

8. Ibid., 15.

9. Ibid., 25.

10. Ibid., 78.

11. Ibid., 80.

12. Ibid., 91-118.

13. Ibid., 120.

14. Robert Moore, "The Filtration of City Water Supplies in the Light of Recent Researches," *Journal of the Association of Engineering Societies*, (May 2, 1894).

15. Ibid., 123.

16. Baker, *Quest for Pure Water*, 140.

17. Ibid.

18. Joseph Cellini, Ed., *Clean Water and the Health of Cities*, (New York: Arno Press, 1977), 489-564.

19. Ibid.

20. Ibid.

21. Jean-Pierre Goubert, *The Conquest of Water: The Advent of Health in the Industrial Age*, (Oxford, England: The Polity Press, 1986), 3-4.

22. Ibid.

23. Allen Hazen, "The Present Status of Methods of Purification of Water in America," *The Engineering Record*, Vol. 42, No. 19, (November 10, 1900).

24. Ibid.

25. Baker, *Quest For Pure Water*, 179.

26. Hazen, "Present Status of Methods."

27. Baker, *Quest For Pure Water*, 115.

28. Ibid., 341.

29. Ibid., 90.

30. H.T. Turner, "The Artificial Filtration of Water," *American Contract Journal*, (April 18, 1885).

31. Baker, *Quest For Pure Water*, 139-178.

32. "Pumping Water for Irrigation in Arizona," *Engineering News*, (May 31, 1894).

33. Painting of Fort Yuma by "Prvt. Will of H cmpy," circa 1853, Arizona Historical Society, Yuma.

34. *A Historic Structure Report: The Officer's Quarters at the Yuma Quartermaster Depot*, (Gerald A. Doyle & Associates, 1988), 48.

35. Henry F. De Corse, "First Yuma Water 'System' Was A Used Whiskey Barrel On A Cart," *Yuma Daily Sun*, (July 19, 1968).

36. William H. Westover, *Yuma Footprints*, (Tucson, Arizona: Arizona Pioneers Historical Society, 1966).

37. De Corse, "First Yuma Water 'System'."

38. Ibid.

39. *The Blaisdell Papers*, Volume 6, Number 8, (Blaisdell Family Association, November 1964).

40. Isabel Buse, "Blaisdells Ran the Water, Power And Phones Back in Early Days," *The* [Yuma] *Sun*, May 5, 1969.

41. Another Blaisdell, Ira, was in Yuma in 1879. His relationship to Hiram and Frank has not been determined. Ira is known, however, to have managed the Southern Pacific Railroad's water system, which also supplied water to some residents of the town. See *The Blaisdell Papers*, (Blaisdell Family Association, November 1964).

42. Robert Woznickii, *History of Yuma and the Territorial Prison*, (Calexico, California: San Diego State College, Imperial Valley Campus, 1968), Chapter 22.

43. "According to notice the stockholders and directors of the Mohawk Valley Canal Company, held a meeting on Wednesday afternoon. The company sold out their franchise and all their rights to a new corporation known as the Mohawk Canal Company. The new company has secured the financial help of a Boston syndicate and proposes to extend the Mohawk Canal 20 Miles and complete the same within one year. The following are the names of the Board of

Directors; J.W. Dorrington, H.W. Blaisdell, F.L. Ewing, J.H. Taggart, and H. Goldwater." See *Arizona Sentinel*, (December 11, 1886) 2:1.

44. Lots 12 and 13 in Section 23 and Lots 4 and 5 in Section 24, Township 8 South, Range 22 West, Gila and Salt River Meridian.

45. *Blaisdell Papers.*

46. Westover, *Yuma Footprints*, 5.

47. N.E. 1/4 of Section 29, the N.W. 1/4 of Section 28 and the S.W. 1/4 of Section 21, Township 8 South, Range 21 West, Gila and Salt River Meridian.

48. *Blaisdell Papers.*

49. Senator Carl Hayden Collection, *Mineral Resources of Yuma County*, rear insert.

50. Buse, "Blaisdells Ran the Water."

51. R.E.L. Robinson, "1893: Yuma Arizona," *The Californian*, (November 1893), 869-878.

52. Ibid.

53. George Wharton James, *Reclaiming the Arid West*, (New York: Dodd, Mead, & Co., 1917).

54. J. Eliot Coit, "Citrus Culture in the Arid Southwest," *Agricultural Experiment Station*, (Tucson: University of Arizona, December 21, 1908) Bulletin No. 58, 286-297.

55. The Reclamation Act created the U.S. Reclamation Service in 1902, and the Secretary of the Interior placed it in the U.S. Geological Survey from 1902 to 1907. Then the U.S. Reclamation Service became an independent agency until 1923 when the name of the agency was changed to the Bureau of Reclamation. See Brit Allan Storey, *The Bureau of Reclamation's Yuma Valley Railroad*, (Denver Office of Bureau of Reclamation, 1990), 2.

56. Woznickii "History of Yuma," and telephone interview with Mark Wilcox, University of Arizona, Co-operative Extension Office, Yuma.

57. Mark Wilcox interview.

58. James, *Reclaiming the Arid West.*

59. *Phoenix Daily Herald*, March 3, 1899, 3:2.

60. E.B. Hart, "First Days at the King," *The Kofas and the King*, (Tucson, Arizona: Calico Print, May 1953).

61. Ibid.

62. Ibid.

63. *Blaisdell Papers.*

64. Ibid.

65. Due to an oversight, the franchise, granted on May 14, 1892, omitted the electric plant until it was revised on December 2, 1892. See Dennis Preisler, "Light Up The Plaza! Electricity on the Arizona Frontier," *The Gazette*, Sharlot Hall Museum of Arizona History, (December, 1990) Number 3.

66. Ibid.

67. "Pumping Water for Irrigation in Arizona."

68. Ibid.

69. "The Birth of Electricity in Yuma", Arizona Public Service Company Corporate Archives, File 4, Box 01-5.

70. C.G. Ekstrom, "History of the Yuma Water Plant," 1941, Arizona Public Service Company Corporate Archives, File 4, Box 01-3.

71. "Yuma Electric Light and Water Company," *Yuma Daily Examiner*, (December 20,1909), Christmas Edition, 60.

72. T. Lindsay Baker, "The Blaisdell Slow Sand Filter Washing Machine," *Arizona Professional Engineer*, (July, 1980).

73. "Pumping Water For Irrigation In Arizona."

74. Robinson, "1893: Yuma Arizona."

75. Robinson, "1893: Yuma Arizona."

76. "Pumping Water for Irrigation in Arizona."

77. Robinson, "1893: Yuma Arizona."

78. "Pumping Water for Irrigation in Arizona."

79. Ibid.

80. Water Claim APS (In Yuma the Colorado River runs in a westerly direction. Thus, there are only north and south banks. The south bank has frequently been erroneously referred to as the east bank.)

81. C.G. Ekstrom, "Yuma and the Colorado River," *AWWA Journal*, (March, 1947).

82. Agreement (ordinance) for Orange Avenue, Arizona Department of Library, Archives and Public Records, RG 139, City of Yuma, Minute Book 2.

83. *Blaisdell Papers*.

84. De Corse, "First Yuma Water 'System'."

85. Ekstrom, "History of the Yuma Water Plant."

86. De Corse, "First Yuma Water 'System'."

87. The Telephone Exchange was later moved to the "Telephone" building at 20 First Street, where a two-position switchboard was built. By 1913 the exchange was owned by Bill Bunton. At that time it was bought by the Mountain States Telephone and Telegraph Company and moved to 285 Second Avenue. See "History of Yuma Telephone Exchange," Arizona Historical Society, Yuma.

88. Westover, *Yuma Footprints*.

89. William B. Fuller, "High Relative Rates of Filtration with Slow Sand Filters," *Engineering News*, (March 12, 1908) Vol. 59, No. 11.

90. Baker, "Blaisdell Slow Sand."

91. Fuller, "High Relative Rates."

92. Baker, "Blaisdell Slow Sand."

93. Fuller, "High Relative Rates."

94. Baker, "Blaisdell Slow Sand."

95. Fuller, "High Relative Rates."

96. Ibid.

97. *Description of the Filtration Works and Pumping Stations also Brief Historical Review of the Water Supply 1789–1900*, (City of Philadelphia, Department of Public Works, Bureau of Water, 1909).

98. The sand filters at Philadelphia were typically cleaned once a month by reverse flow wash which flowed into sewers through a 20" pipe drain. Two sand washers in the court outside the filters received the dirty water and sand in a series of hoppers. "The sand finds its way to the bottom of the hopper and is ejected to the next hopper. The dirty water overflows from the hoppers and passes to the sewer." See letter from Ed Grusheski included in Field Reports, images of standard washing procedure and Blaisdell machine included.

99. "Water Purification at Wilmington, Delaware," *The Engineering Record*, (November 20, 1909) Vol. 60, No. 21.

100. "Intermediate Rate Fine-Sand Water Filter Operates Under Vacuum," *Engineering News-Record*, (June 27, 1918) Vol. 80, No. 26.

101. Ibid.

102. Ekstrom, "History of the Yuma Water Plant."

103. Ibid.

104. "The Birth of Electricity in Yuma," APS.

105. Ekstrom, "History of the Yuma Water Plant."

106. Ibid.

107. 1925 according to Ekstrom. Ibid.

108. Ibid.

109. Ekstrom, "Yuma and the Colorado River."

110. Preisler, "Light Up the Plaza!"

BIBLIOGRAPHY

BOOKS

Baker, Moses Nelson. *The Quest for Pure Water.* New York: The American Water Works Association, Inc., 1948. Lancaster, Pennsylvania: Lancaster Press, Inc. 1949.

Cellini, Joseph, Ed. *Clean Water and the Health of Cities*. New York: Arno Press. 1977.

Crowe, Rosalie. *Early Yuma: A Graphic History of Life on the American Nile*. Flagstaff, Arizona: Northland Press. 1976.

Dunning, Charles with Edward H. Peplow Jr. *Rocks to Riches*. Phoenix, Arizona: Southwest Publishing Company, Inc. 1959.

Goubert, Jean-Pierre. *The Conquest of Water.* Oxford, England: The Polity Press. 1986.

Hart, E.B. "First Days at the King." *The Kofas and the King*. Tucson, Arizona: Calico Print. May, 1953.

James, George Wharton. *Reclaiming the Arid West*. New York: Dodd, Mead, & Co. 1917.

King, Cameron. *The Citrus and Fruit Belt of Southern Arizona*. San Francisco: Crocker & Co.'s Print. 1887.

Swanson, Mark T. and Jeffery H. Altschul. *Cultural Resources Investigation of the Yuma Quartermaster Depot*. Arizona Department of Transportation in cooperation with Arizona State Parks. 1991.

Trafzer, Cliff and Steve George. *Prison Centennial 1876-1976*. Yuma, Arizona: Rio Colorado Press. 1978.

Westover, William H. *Yuma Footprints*. Tucson, Arizona: Arizona Pioneers Historical Society. 1966.

Woznickii, Robert. *History of Yuma and the Territorial Prison*. Calexico, California: San Diego State College, Imperial Valley Campus. 1968.

PERIODICALS

Baker, T. Lindsay. "The Blaisdell Slow Sand Washing Machine." *Arizona Professional Engineer*. July, 1980.

Coit, Eliot J. "Citrus Culture in the Arid Southwest." Tucson, Arizona: *University of Arizona Agricultural Experiment Station Bulletin*. No. 58. December 21, 1908.

Doan, May C. "Reminiscence of May C. Doan." *Journal of Arizona History*. Vol. 6, p. 116-131. Autumn, 1965.

Drown, Thomas M. "The Filtration of Natural Waters." *Journal of the Association of Engineering Societies*. January 15, 1890.

Ekstrom, C.G. "Yuma and the Colorado River." *American Water Works Association Journal.* March, 1947.

Engineering News. "Pumping Water for Irrigation in Arizona." May 31, 1894.

Engineering News Record. "Intermediate Rate Fine-Sand Water Filter Operates Under Vacuum." June 27, 1918.

Engineering Record. "Water Purification at Wilmington Delaware." November 20, 1909.

Fuller, George W. "Continuous and Intermittent Sand Filtration of Water." *Engineering News*. October 4, 1894.

Fuller, William B. "High Relative Rates of Filtration with Slow Sand Filters." *Engineering News*. March 12, 1908.

Fuller, William B. "The Purification of Water by Sand Filtration." Proceedings of Annual Meeting of the Connecticut Society of Civil Engineers. *Engineering News*. February 20, 1908.

Hazen, Allen. "The Present Status of Methods of Purification of Water in America." *Engineering Record*. November 10, 1900.

Hoopes, Edgar M. Jr. "Air Bound Filters the Chief Difficulty in Operating Wilmington's Water Purification Plant." *Engineering Record*. September 4, 1915.

Moore, Robert. "The Filtration of City Water Supplies in the Light of Recent Researches." *Journal of the Association of Engineering Societies*. May 2, 1894.

Preisler, Dennis. "Light Up The Plaza! Electricity on the Arizona Frontier." *The Gazette*. Sharlot Hall Museum of Arizona History. December, 1990.

Robinson, R.E.L. "1893: Yuma Arizona." *The Californian*. November, 1893. p. 868-878.

Russel, S. Bent. "Notes on Certain Points in the Design of Large Filtration Plants." *Journal of the Association of Engineering Societies*. June, 1909.

Turner, H.T. "The Artificial Filtration of Water." *American Contract Journal*. April 18, 1885.

NEWSPAPERS

Arizona Republic. Arizona Days and Ways, January 1, 1956.
Arizona Republic. February 25, 1964.
Arizona Republic. September 12, 1976.

Arizona Sentinel. December 11,1886.
Arizona Sentinel. March 28, 1891.
Arizona Sentinel. May 2, 1891.
Arizona Sentinel. February 20, 1892.
Arizona Sentinel. April 16, 1892.
Arizona Sentinel. June 4, 1892.
Arizona Sentinel. October 15, 1892.
Arizona Sentinel. January 14, 1893.
Arizona Sentinel. March, 7, 1906.
Phoenix Daily Herald. March 3, 1899.
Yuma Daily Examiner. December 20, 1909.
Yuma Daily Sun. July 19, 1968.

Unpublished Materials

Letter from Ed Grusheski, Director of Water Works Interpretive Center, City of Philadelphia. June 25, 1993.

Archival Collections

Arizona Historical Society, Yuma

Blaisdell Papers Vol. 6. Blaisdell Family Association. November, 1964.

Arizona Public Service Company Corporate Archives

File 4, History: Yuma Water and Light Company, 1893 Franchise, Box 01-5 History of Arizona Edison

File 4, History: Yuma Water Plant, 1941, Box 01-3 History of Tapco, Nalapco, History of Arizona Edison

File 17, Old Commission Cases, Box 01-147 History of Arizona Edison, Calapco Rate Case.

Arizona State University

Mineral Resources of Yuma County. Collection compiled by U.S. Senator Carl Hayden

Public Documents

Description of the Filtration Works and Pumping Stations. City of Philadelphia, Department of Public Works, Bureau of Water. 1909.

Storey, Brit Allen. *The Bureau of Reclamation's Yuma Valley Railroad*. Denver office of Bureau of Reclamation. 1990.